Tappi

THE JOURNAL OF THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY

JANUARY 1961

VOLUME 44 • NUMBER 1

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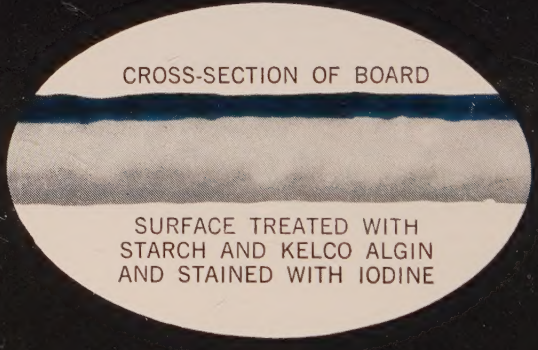

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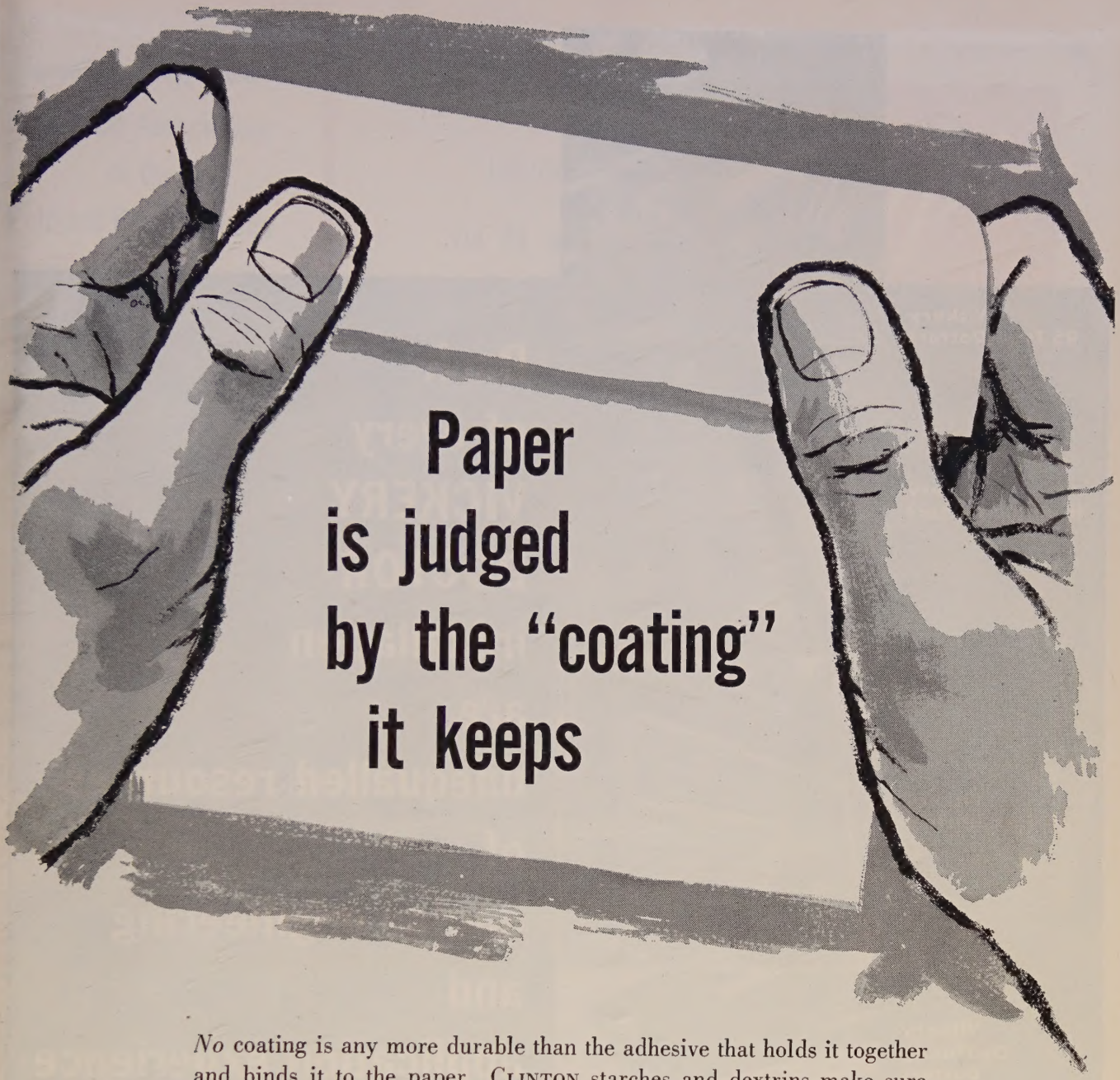

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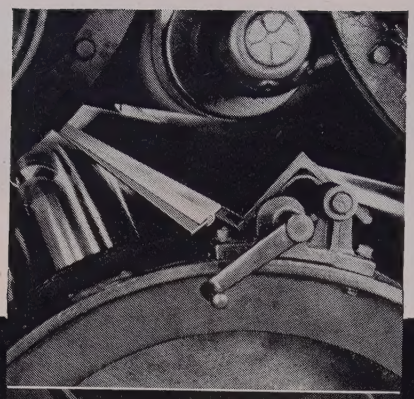

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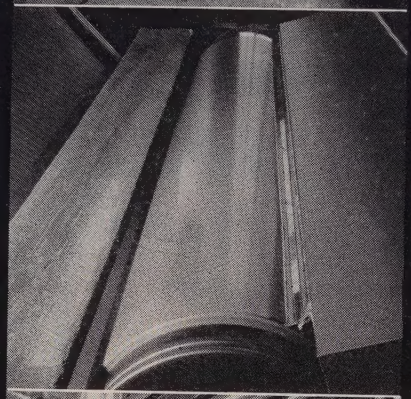

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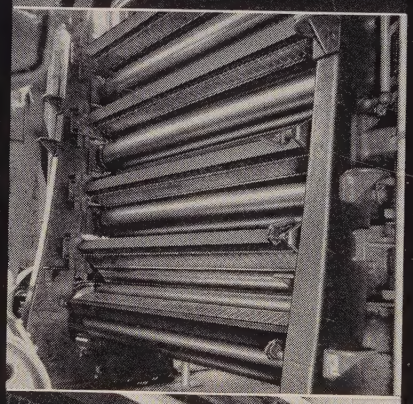

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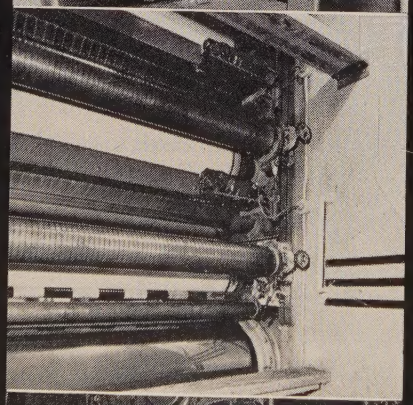
Hi-Flex Doctors



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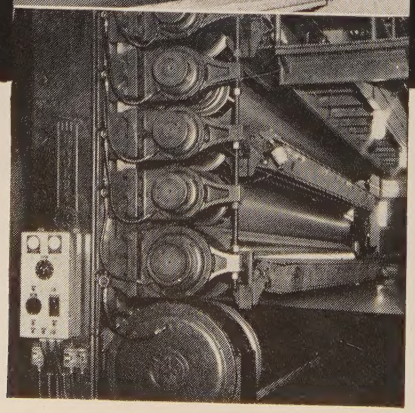
Doctors



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46th Annual Meeting
Commodore Hotel, New York, N. Y.
Feb. 19–23, 1961

Twelfth Coating Conference
Statler-Hilton Hotel, Buffalo, N. Y.
May 8–10, 1961

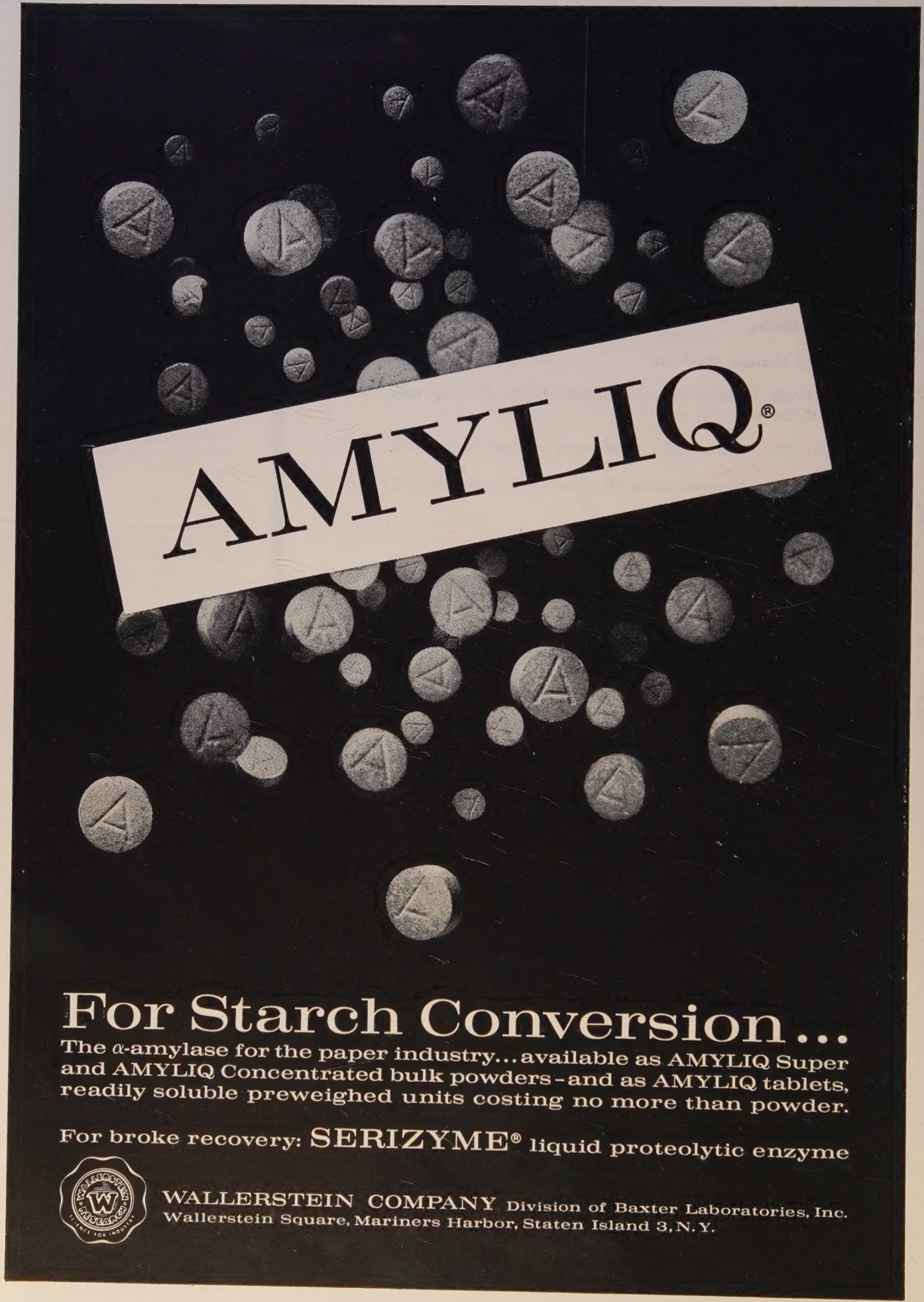
Lignin Symposium
Edgewater Beach Hotel, Chicago, Ill.
Aug. 14–16, 1961

Twelfth Testing Conference
Queen Elizabeth Hotel, Montreal, Que.
Aug. 15–18, 1961

Eleventh Corrugated Containers Conference
St. Francis Hotel, San Francisco, Calif.
Sept. 11–13, 1961

Fourth Mechanical Pulping Conference
(Tech. Sect., CPPA–TAPPI)
Edgewater Beach Hotel, Chicago, Ill.
Sept. 19–21, 1961

Please refer to Local Section Activities for the locations and dates of Section meetings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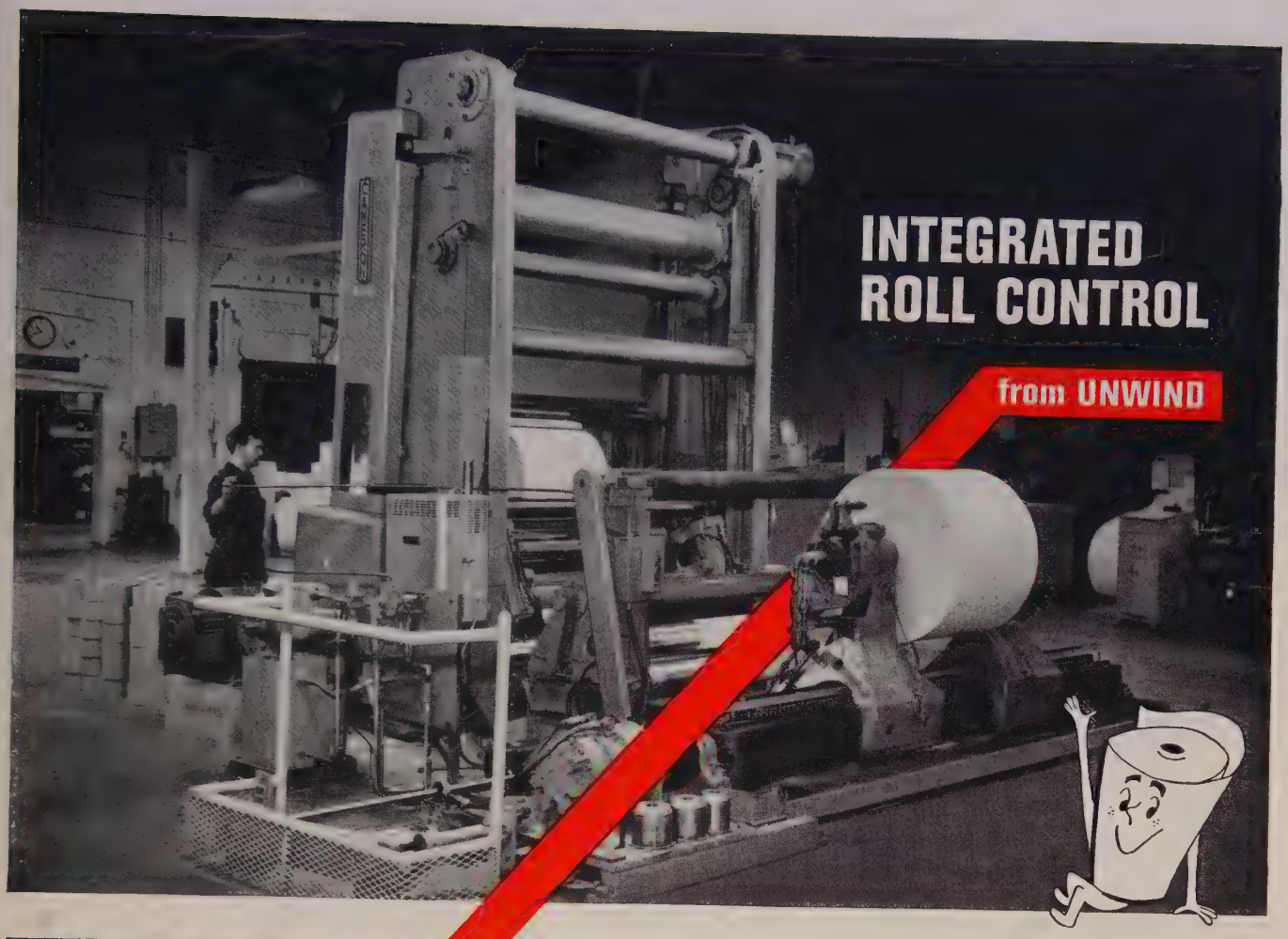

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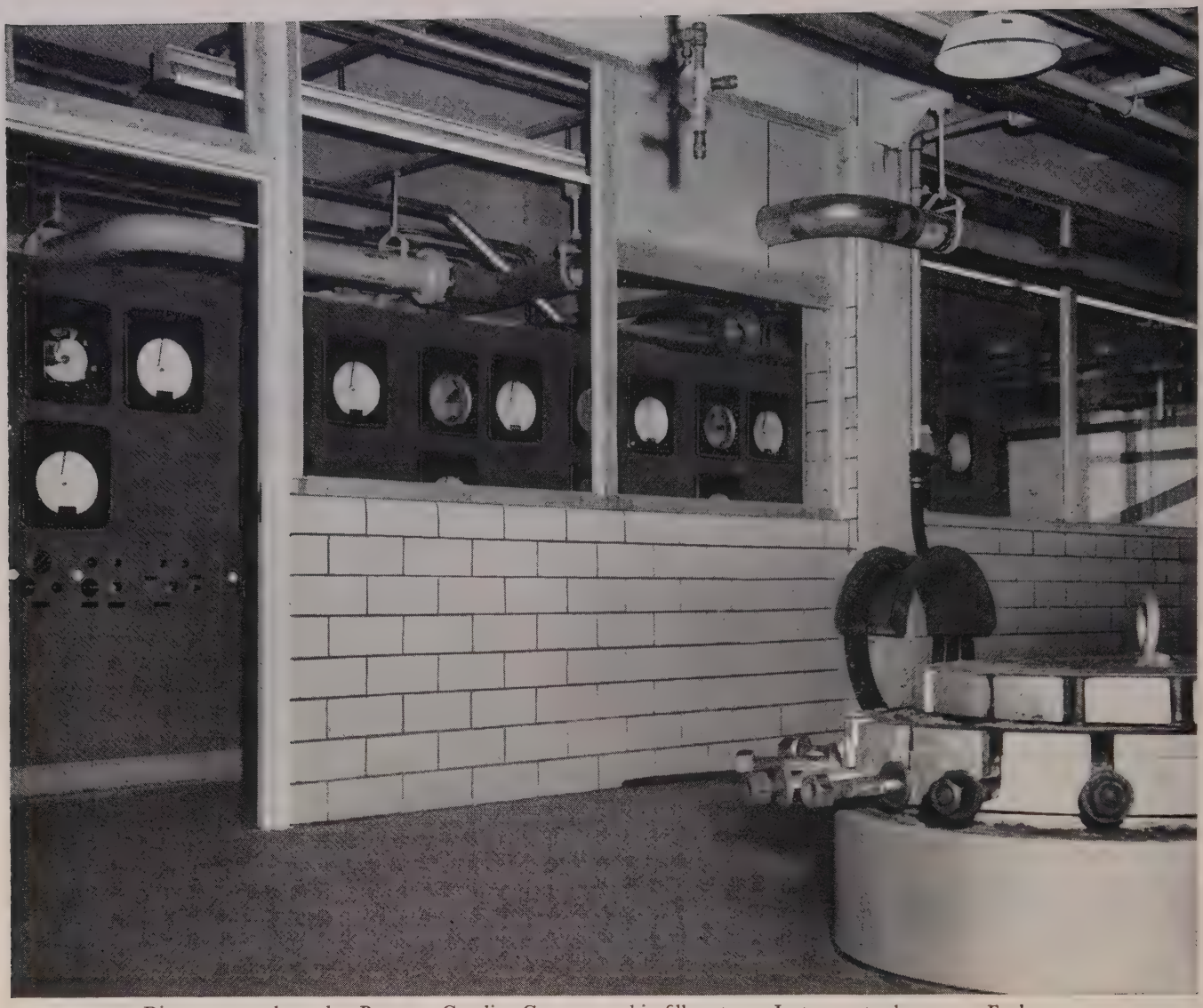

Digester control panel at Bowaters Carolina Corp., Catawba, S. C., containing 5 Foxboro Digester Control Systems, together with liquor-fill and chip-fill systems. Instruments shown are Foxboro cam pressure controllers, digester top-and-bottom temperature recorders, and relief flow controllers.

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TAPPI Annual Meeting Program

Commodore Hotel, New York, N. Y., Feb. 20–23, 1961

Forty-Sixth Annual Meeting

The Forty-Sixth Annual Meeting of the Association will be held on Feb. 20–23, 1961, at the Hotel Commodore in New York, N. Y. The technical program below is as accurate and firm as is now possible. However, some changes may occur, hence travel plans probably should not be made wholly on the basis of the program as shown.

PROGRAM

MONDAY, FEBRUARY 20, 1961

9:00 a.m. Sulfite Pulping Session I (West Ball Room)

P. E. Trout, Waldorf Paper Products Co., St. Paul, Minn., *Chairman*

1. "History and Application of the Kopparfors Lining," by R. A. Mennes, I. Olson, and A. Ahlstrom.
2. "The Kopparfors Bag-Type Digester Lining," By G. Cape.
3. "The Mechanism of Acid Bisulfite Pulp I. Batch Pulping," by W. J. Nolan, University of Florida, Gainesville, Fla.
4. "The Estimation of Spent Sulfite Liquor Concentration in Natural Waters," by V. F. Felicetta and J. L. McCarthy, Univ. of Washington, Seattle, Wash.

9:00 a.m. General Session I (Windsor Ball Room)

1. "Steam Stripping of Volatile and Odorous Substances from Kraft Pulp Mill Aqueous Streams," by M. J. Matteson, L. N. Johanson and J. L. McCarthy, Univ. of Washington, Seattle, Wash.
2. "High Efficiency Wet-Strength Resins," by C. S. Maxwell and R. R. House, American Cyanamid Co., Stamford, Conn.
3. "The Effect of Colors on the Opacity of Paper," by M. Hayek, A. S. Deutsch and J. P. Neary, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.
4. "The Material Balance of a Nitric Acid Pulping Process," by D. L. Brink, University of California, Richmond, Calif.

9:00 a.m. Alkaline Pulping Session (Windsor Terrace)

T. T. Collins, Packaging Corp. of America, Filer City, Mich., *Chairman*

1. "New Venturi Scrubber Developments—The Steam Atomized Venturi," by P. H. West, Thilmany Pulp & Paper Co., Kaukauna, Wis., H. P. Markant and J. H. Coulter, Babcock & Wilcox Co., Barberton, Ohio.
2. "Measurement of Kamyr Continuous Kraft Digester Cooking Cycle Using Radioactive Tracers," by R. P. Hamilton, St. Regis Paper Co., Deferiet, N. Y.
3. "A Rational Approach to Recovery Furnace Dissolvant Tank Design," by C. R. P. Cash, Fibreboard Paper Products Corp., San Francisco, Calif.
4. Kraft versus NSSC Pulping," by H. B. Wilder and S. T. Han, The Institute of Paper Chemistry, Appleton, Wis.
5. "Free Hydroxide as a Control in Kraft Cooking," by E. T. O'Brien, H. D. Bauman, and R. F. Cashen, P. H. Glatfelter Co., Spring Grove, Pa.

2:00 p.m. Manpower Symposium Session (Grand Ball Room)

W. G. Torpey, Office of Civil Defense Mobilization, Washington, D. C., *Chairman*

1. "The Role of Engineering Technicians to Relieve Technical Personnel of Nonprofessional Tasks."
2. "Parallel Incentive Systems for Nonsupervisory and Supervisory Technical Personnel."
3. "The 'First Five Year' Plan of the Engineers Joint Council for Professional Development."

2:00 p.m. Chemical Methods Session (Windsor Ball Room)

W. K. Wilson, National Bureau of Standards, Washington, D. C., *Chairman*

1. "The Spectrophotometric Determination of Lignin in Small Wood Samples," by D. B. Johnson, W. E. Moore, and L. C. Zank, Forest Products Laboratory, Madison, Wis.
2. "Qualitative Analysis of Fiber Blends," by K. Wharton, National Bureau of Standards, Washington, D. C.
3. "Spectrophotofluorometric Studies of Degraded Cotton Celluloses," by S. D. Toner and K. F. Plitt, National Bureau of Standards, Washington, D. C.
4. "A Study of the Fluorescence of Cellulosic Polymers," by K. F. Plitt and S. D. Toner, National Bureau of Standards, Washington, D. C.
5. "Measurement of the pH of Paper by Means of a Surface Test with Glass Electrodes," by J. H. Flynn and L. E. Smith, National Bureau of Standards, Washington, D. C.

9:00 a.m. Corrosion Session I (Grand Ball Room)

H. B. Harris, Union Bag-Camp Paper Corp. Savannah, Ga., *Chairman*

1. "Corrosion in Tall Oil Processing," by H. C. Templeton, Alloy Steel Products Co. Linden, N. J.
2. "Electrolytic Corrosion Protection of Paper Mill Equipment," by T. R. B. Watson, Corrosion Service, Ltd., Toronto, Ont., and W. A. Mueller, Pulp & Paper Research Institute of Canada, Montreal, Que.
3. "Report on Project No. 839—"Corrosion Experience in ClO_2 Bleaching," questionnaire by R. E. L. Wheless, Union Bag-Camp Paper Corp., Franklin, Va.
4. "Manufacture and Proper Specifications for Type 304 Welded Stainless Steel Tubing for Kraft Evaporator Service," by S. E. Doughty and W. J. Comerford, Carpenter Steel Co., Union, N. J.

9:00 a.m. Cylinder Board Session I (West Ball Room)

1. "Fundamentals of Drying Thick Porous Bodies," by A. H. Nissan, Rensselaer Polytechnic Institute, Troy, N. Y.
2. "Systems Available for Controlling Drying," by representative from Mason, Neilan Div.
3. "Mill Experience with the Stamm Moisture System," by representative from Packaging Corp. of America.
4. "Mill Experience with the Foxboro Moisture System," By W. O. Kroeschell, Michigan Carton Co., Battle Creek, Mich.
5. "Mill Experience with the Stickle System," by representative from New Haven Board & Carton Co.

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TUESDAY, FEBRUARY 21, 1961

9:00 a.m. Sulfite Pulping Session II (Windsor Ballroom)

W. A. Chilson, U. S. Forest Products Laboratory, Madison, Wis., *Chairman*

1. "The Influence of Wood Damage on Sulfite Pulp Quality," by J. E. Stone, Pulp & Paper Research Institute of Canada, Montreal, Que.
2. "Theory and Practice of a Norman Chipper," by E. L. Crowley, Carthage Machine Co., Hapeville, Ga.
3. "New Chipper Design Features and Their Effect on Cooking Yields," by R. M. Buechler, L. L. Duncan, and J. Haller, D. J. Murray Mfg. Co. Wausau, Wis.
4. "Sulfite Pulping of Saw Kerf Chips from Douglas-Fir," by N. Sanyer and E. L. Keller, U. S. Forest Products Laboratory, Madison, Wis.
5. Panel Discussion.

9:00 a.m. Statistics Session I (Windsor Terrace Room)

J. F. Langmaid, Jr., S. D. Warren Co., Cumberland Mills, Me., *Chairman*

1. "Cumulative Sum Charts—A New Tool for Control of Manufacturing Processes," by H. Mack Truax, Atlas Powder Co., Wilmington, Del.
2. "Examples of Industrial Applications of Designed Experiments," by Dorian Shainin, Rath & Strong, Inc., Boston, Mass.

9:00 a.m. Chemical Products Session I (Room B-C)

Paul R. Wiley, West Virginia Pulp & Paper Co., Charleston, S. C., *Chairman*

1. "Investigations on the Mechanism of Lignification," by Walter J. Schubert and F. F. Nord, Fordham University, New York, N. Y.
2. "Decomposition of Lignin. I. Action of Compounds of the Type $RNH_{1-3}X$," by Donald H. Grangaard, Kimberly-Clark Corp., Neenah, Wis.
3. "The Degradation of Spruce Periodate-Formaldehyde Lignin by New Methods," by M. R. Jain, McGill University Montreal, Que., and C. B. Purves, Pulp & Paper Research Institute of Canada, Montreal, Que.
4. "De-etherification of Lignin by Aqueous Chlorine Solutions," by K. V. Sarkanen, Cellulose Research Institute, State University College of Forestry at Syracuse University, Syracuse, N. Y., and R. W. Strauss, Nekoosa-Edwards Paper Co. Port Edwards, Wis.

2:00 p.m. Corrosion Session II (Grand Ball Room)

R. C. Stamm, West Virginia Pulp & Paper Co., New York, N. Y., *Chairman*

1. "Stainless Steel Overlay Installation," by C. R. Jelm, American Alloy Corp., Cleveland, Ohio.
2. "Report on Project No. 522—Alkaline Digester Corrosion," by H. M. Canavan, Mutual Boiler & Machine Insurance Co., Waltham, Mass.
3. Open discussion on stainless steel overlay.

2:00 Cylinder Board Session II (West Ball Room)

1. "Mill Experience with Hurletron System."
2. "Mill Experience with the Brown System."

Panel Discussion

2:00 p.m. Chemical Products Session II (Room B-C)

E. G. Locke, U. S. Forest Products Laboratory, Madison, Wis. *Chairman*

1. "Investigations on Hardwood Lignins," by Carmine J. Cosica and Walter J. Schubert, Fordham University, New York, N. Y.
2. "Examination of Western Hemlock Cambium for Lignin Precursors," by Otto Goldschmid and H. L. Hergert, Rayonier, Inc., Shelton, Wash.
3. "The Commercial Production of Acetic and Formic Acids from Neutral Sulfite Semichemical Black Liquor," by W. A. Biggs, Jr., J. T. Wise, W. R. Cook, W. H. Baxley, J. D. Robertson, and J. E. Copenhauer, Sonoco Products Co., Hartsville, S. C.

1:15 p.m. Corrugated Container Session I (Windsor Ball Room)

R. C. Hutcheson, Union Bag-Camp Paper Corp., Spartansburg, S. C., *Chairman*

Theme: "Stop and Take Count"

A. Richardson, Gaylord Container Div., Crown Zellerbach Corp., St. Louis, Mo., *Moderator*

1. "The Performance of 39 Tooth-C Flute Rolls," by T. B. Haire, Continental Can Co.
2. "Hooper Knife Results—A Three-Year Trial," by R. W. Catzen, Baltimore Paper Box Co., Baltimore, Md.
3. "Langston Electronically Controlled Knife-Operating Results," by John Thompson, Hy-Grade Containers.
4. Question-and-Answer Period

2:00 p.m. Dissolving Pulp Session (Windsor Terrace)

M. Heath, The Buckeye Cellulose Corp., Memphis, Tenn., *Chairman*

1. "Studies of Viscose Filtration," by M. E. Kinsey, Tee-Pak, Inc., Danville, Ill., and F. K. Mesek, Johnson & Johnson, Chicago, Ill.
2. "Investigation of Cellulose Acetate—Propionate Plastics," by L. H. Sperling, Buckeye Cellulose Corp., Memphis, Tenn.
3. "Kinetics of the Thermal Degradation of Cellulose Nitrate as Measured by an Improved Taliani Procedure," by Merill A. Millett, R. M. Seborg, L. L. Zock, U. S. Forest Products Laboratory, Madison, Wisc., and F. J. Masuelli, Commanding Officer, Picatinny Arsenal, Dover, N. J.
4. "Preparation and Properties of Sulfoethyl Cellulose," by L. F. McBurney and V. R. Grassie, Hercules Powder Co., Wilmington, Del.

WEDNESDAY, FEBRUARY 23, 1961

9:00 a.m. Fourdrinier Session (Room B-C)

W. H. Kennedy, The Black-Clawson Co., Watertown, N. Y., *Chairman*, and R. W. Peters, Eastman Kodak Co., Rochester, N. Y., *Moderator*

9:00 a.m. Graphic Arts Session I (Grand Ball Room)

James H. Wing, Continental Can Co., Inc., Uncasville, Conn., *Chairman*

1. "Box Shop Quality Control," by R. Harlow, Continental Can Co., Inc., Uncasville, Conn.
2. "Microcomponents of Printing and Their Effect on Mass Appearance—Illustrated with Photomicrographs and Case Histories," by E. Schmatolla, Rogers Kellogg Corp. Long Island City, N. Y.
3. "Heat Transfer Printing," by R. D. Sheppard, Dennison Mfg. Co., Framingham, Mass.
4. "Mill Experience with the Elvasize Process," by B. A. Beardswood and C. J. Stapf, Jr., E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.
5. "Development of a Test Method for Surface Strength Evaluation," by W. D. Shaeffer, C. E. Grund, J. M. Fetsko, and A. C. Zettlemoyer, Lehigh University, Bethlehem, Pa.

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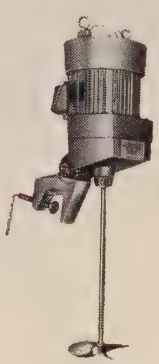

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9:00 a.m. Pulp Purification Session I (West Ball Room)

F. KRAFT, Marathon Corp., Menasha, Wis., *Chairman*

1. "Mill Trial of the R-2 Chlorine Dioxide Process," by H. D. Partridge, Hooker Electrochemical Corp., Niagara Falls, N. Y., and W. H. Rapson, University of Toronto, Toronto, Ont.
2. "Metal Catalysis in Hypochlorite Bleaching," by J. H. E. Herbst, Industrial Cellulose Research, Ltd., Hawkesbury, Ont.
3. "Chelating Agents in the Stabilization of Groundwood Peroxide Bleaching Systems," by R. D. Spitz, Dow Chemical Co., Midland, Mich.
4. "Carbonyl Groups and Brightness Reversion," by W. H. Rapson, University of Toronto, Toronto, Ont.
5. "Chlorine Demand of Pulps," by G. H. Baldauf and Bjorn O. Lehto, Allied Paper Corp., Kalamazoo, Mich.

9:00 a.m. Corrugated Container Session II (Windsor Ball Room)

THOMAS W. CARROLL, Owens-Illinois, Toledo, Ohio, *Chairman*

Theme: "Use of Industrial Engineering Services by Organizations"

1. "The Use by Line Organization of Industrial Engineering Services," (Introduction of theme), by H. A. Buckley, Standard Paper Box, Ltd., Montreal, Que.
2. "Wage Payment Policies and Practices," by E. Rohde, Elliot Rohde Associates, New York, N. Y.
3. "Methods Improvement," by J. C. Sprague, Green Bay Box Co., Green Bay, Wis.
4. "Production Reporting," by C. Craigo, Hercules Box Co., New York, N. Y.
5. "The Use of Work Measurement," by F. H. Cloud, Packaging Corp. of America, Central Region, Grand Rapids, Mich.
6. "Industrial Engineering in Waste Control," by R. J. Buckley, Bathurst Containers, Ltd., Whitby, Ont.
7. "In-Plant Supervisory Training," by R. S. Owen, R. S. Owen & Co., Chicago, Ill.

9:00 a.m. Statistics Session II (Windsor Terrace)

M. S. RENNER, Dewey & Almy Chemical Co., Cambridge, Mass., *Chairman*

1. "The TAPPI Statistics Committee Attributes Sampling Program," by W. E. Carlson, St. Regis Paper Co., Carthage, N. Y.
2. "Sequential Start-up Procedure for a Pulp-Drying Machine," by J. Glenn Olree, The Buckeye Cellulose Corp., Memphis, Tenn.
3. "Application of Probability Theory to Paper Structure," by O. Kallmes, St. Regis Paper Co., Carthage, N. Y.
4. "Technologies of Total Quality Control," by W. J. Masser, General Electric Co., New York, N. Y.

2:00 p.m. Graphic Arts Session II (Grand Ball Room)

L. E. DELAUTER, West Virginia Pulp & Paper Co., New York, N. Y., *Chairman*

1. "Letterpress Inks—What Problems Do They Pose for the Papermaker?," by Philip T. Pope and W. F. Douglas, Pope and Gray, Inc., Clifton, N. J.
2. "Lithographic Inks and Developments in Lithography," by Victor J. Porth, Interchemical Corp., New York, N. Y.
3. The Present Status of Flexographic Ink—Developments Over the Past Ten Years," by R. Scott, Sinclair & Valentine Co. Secaucus, N. J.
4. "Gravure Inks in Relationship to Printing Surfaces," by W. S. Webster, Commercial Ink & Lacquer Co., Fair Lawn, N. J.

2:00 p.m. Pulp Purification Session II (West Ball Room)

H. L. CROSBY, The M. W. Kellogg Co., New York, N. Y., *Moderator*

Panel Discussion—"Operation and Control of Bleach Plants"
W. L. Orr, St. Regis Paper Co., Pensacola, Fla.
G. W. Seymour, Brunswick Pulp & Paper Co., Brunswick, Ga.
R. H. Taylor, Finch Pruyn & Co , Glens Falls, N. Y.
L. Hinton, Fraser Paper Co., Edmundston, N. B.
J. M. McEwen, Weyerhaeuser Co., Everett, Wash.

2:00 p.m. Corrugated Container Session II (Windsor Ball Room)

Theme: "Use of Industrial Engineering Services in Line Organizations"

T. W. CARROLL, Owens-Illinois, Toledo, Ohio, *Chairman*
Continuation of Session II

1. "Equipment Replacement," by F. C. Came, Union Bag-Camp Paper Corp., New York, N. Y.
2. Question-and-Answer Period.
3. Panel Discussion by Engineering Committee.

2:00 p.m. Structural Fibrous Materials Session (Windsor Terrace)

W. H. MCPHERSON, Minnesota & Ontario Paper Co., International Falls, Minn., *Chairman*

1. "Rate of Water Vapor Transfer in Wood Fiber Board," by D. R. Ziegler, Washington State University, Pullman, Wash.
2. "The Application of Hi-Yield Pulping Techniques to Hardwoods and Softwoods for Production of Insulation and Hardboard Stocks," by L. E. Eberhardt, Bauer Bros. Co., Springfield, Ohio (to be read by W. McNeil).
3. "Creep in Bending of Insulating Fiber Board Roof Deck," by T. N. Blau, Johns-Manville Research Center, Manville, N. J.
4. "Fire Testing Procedures," by R. H. Neisel, Johns-Manville Research Center, Manville, N. J.
5. "Moisture and Temperature Distribution During Drying of Insulation Board," by K. O. Johnson, Minnesota & Ontario Paper Co.

2:00 p.m. Microbiological Session (Room B-C)

B. F. SHEMA, Betz Laboratories, Inc., Philadelphia, Pa., *Chairman*

1. "A Biological Binder in Paper Mill Slimes," by R. A. Apperman and L. L. Wolfson, Nalco Chemical Co.
2. "Sulfate—Reducing Bacteria—Their Production of Sulfide and Relations to Iron Corrosion," by R. L. Starkey, Rutgers, State University, New Brunswick, N. J.
3. "Nuisance Algae in Water Supplies," by C. Mervin Palmer, R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio.
4. "Biological Deterioration of Wood Chips While in Storage," (tentative title), by R. M. Lindgren, U. S. Forest Products Laboratory, Madison, Wis.

THURSDAY, FEBRUARY 23, 1961

9:00 a.m. Water Session (West Ball Room)

R. J. BAKER, Wallace & Tiernan, Inc., Belleville, N. J., *Chairman*

1. "Combined Cleaning—Thickening—Waste Disposal," by R. Lawless, Lawless Bros, Inc., E. Rochester, N. Y.
2. "Review of Water Treatment Practices and New Developments," by O. V. Lindell, Dorr Oliver, Inc., Stamford, Conn.

9:00 a.m. Adhesives Session (Room B-C)

R. C. BROWN, U. S. Envelope Co., Metuchen, N. J., *Chairman*

1. "The Adhesion Machine," by Miss E. Weizenhoffer and F. C. Campins, Polymer Industries, Inc., Springdale, Conn.

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2. 'Effect of Viscosity on the Penetration of Adhesives into Paper," by Miss R. M. K. Cobb, Lowe Paper Co., Ridgefield, N. J.
3. "Surface Analysis and Adhesion," by W. T. M. Johnson, E. I. du Pont de Nemours & Co., Philadelphia, Pa.
4. "Factors Which Effect Adhesion of Cellulose Fibers in Paper," by John W. Swanson, The Institute of Paper Chemistry, Appleton, Wis.

9:00 a.m. Agricultural Fibers Session (Windsor Terrace)

J. E. Atchison, Parsons & Whittemore, New York, N. Y., *Chairman*

1. "Continuous Soda Pulping, Bleaching and Papermaking of Esparto Grass," by J. N. McGovern and J. Grant, Parsons & Whittemore, New York, N. Y.
2. "Dimensions of the Fibers of Non woody Plant Materials in Relation to their Utilization for the Manufacture of Paper," by R. E. Perdue, Jr., U. S. Department of Agriculture, Beltsville, Md.
3. "A Search for New Fiber Crops. III. Laboratory-Scale Pulping Studies," by G. H. Nelson, H. J. Nieschlag, M. E. Daxenbichler, I. A. Wolff, and R. E. Perdue, Jr., Northern Regional Research Laboratory, United States Dept. of Agriculture, Peoria, Ill.
4. "A Search for New Fiber Crops. V. Pulping Studies on Kenaf," by T. F. Clark, G. H. Nelson, H. J. Nieschlag, and I. A. Wolff, Northern Regional Research Laboratory, United States Dept. of Agriculture, Peoria, Ill.
5. "Newsprint from Domestic Timber Bamboo—*Phyllostachys bambusoides.*"

Committee Meetings

Sunday, February 19—Morning

Sunday, February 19—Afternoon

Alkaline Pulping	Room G
Testing Division Steering	Room E
Engineering Data	Room F
Testing Division Officers Social	Room A

Monday, February 20—Morning

Graphic Arts	Room A
Microbiological Committee	Room E
Pulp Purification Committee	Room F
Routine Control Methods Committee	East Ball Room Parlor
Corrugated Container Process & Quality Control	Room G
Industrial Engineering & Materials Handling Committee	
Statistics Committee	Room 1006
Paperboard	Room 1004
Water Subcommittees	Hq. Conference Room. 360 Lexington Ave.

Monday, February 20—Afternoon

Coating Committee	Room B
Plastics Committee	Room C
Cylinder Board Committee	Room E
Wet Strength Committee & Interfiber Bonding Committee	Room F
Chemical Methods Committee	Room G
Chemical Products Committee	Room 1004
Dissolving Pulp Committee	Room 1006
Engineering Economics Committee	Room 1008
Quality Control Subcommittee (Statistics)	Room 1020
Paper Committee	Room A
Paper Shipping Sack Committee	Room 1016
Packaging Materials Committee	Room 1032
Water Subcommittees	TAPPI Hq.
Engineering Div. Officers	TAPPI Hq.

Tuesday, February 21—Morning

Water Committee	Room A
Training & Education Committee	Room E
Industrial Engineering Committee	Room F
Corrugated Container Production Committee	Room 1004
Fillers & Pigments	Room 1006
Container Testing Committee	Room G
Textbook Subcommittee	Room 1008
Fibrous Raw Materials Committee	Room 1016
Adhesive Committee	Room 1020
Construction Engineering Committee	East Ball Room Parlor
Pulp & Papermaking Chemicals Committee	Room 1032
Release Coatings Committee	Room 1036
Mechanical Pulping	Room 1040
Pulp Testing	Room 1044

Tuesday, February 21—Afternoon

Structural Fibrous Materials Subcommittee	Room A
Beater Additives Committee	Room E
Chemical Engineering Committee	Room F
Sulfite Pulping Committee	Room 1004
Subcommittee on Pigment Studies of Coating Committee	Room 1006
Electrical Engineering Steering Committee	Room 1008
Optical Methods Committee	Room 1016
Physical Methods Committee	Room 1020

Wednesday, February 22—Morning

Structural Fibrous Materials General Committee	Room A

Wednesday, February 22—Afternoon

Corrosion Committee	Room A
Precision Committee	Room 1004

Thursday February 23

Fundamental Research Committee	Room A

Thursday, February 23

Agricultural Fibers Committee	Room A

THIS PULP WAS MADE AT A MILL THAT DOES NOT YET EXIST!

The mill will be our new 85,000-ton plant at Woodfibre, British Columbia. It won't be on stream until May, 1961—but when it is, it will turn out a paper-making pulp identical to the piece attached to this page!

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A Wall Street View of the Paper Industry

LOUIS T. STEVENSON

I FEEL quite at home among a bunch of papermakers and am sure that I should be called a "papermaker in Wall Street" rather than a security analyst. I have, however, been absorbing some of the Wall Street attitudes in my last $7^1/_2$ years and will try to reflect some of them to you.

First we will discuss some of the mechanics by which the vast and important function of maintaining a free market for securities operates.

How They Operate

Members of the New York Stock Exchange have research departments which are staffed with security analysts. For evaluating a company, analysts use financial reports, personal interviews, and any available source of information including security analysts meetings, forums, etc.

Why

Because Wall Street has a stake in the industry.

The largest security market in the world must be informed on the paper industry for advising customers, and managing finances, bond issues, stock issues, consolidations, sale of secondary blocks, and normal trading.

How Does Wall Street Function

There are a number of stock exchanges in the United States, two of them, the New York and the American are located in New York City. The New York Stock Exchange is by far the largest and most important in the world. Here and in the others a daily auction market is maintained. In our shop we regularly follow the market behavior of 29 primary manufacturers of paper. The stocks of two of them are traded over-the-counter, that is, bought and sold outside of any organized stock exchange. The others are listed on the "Big Board."

The organized exchanges have listing requirements principally related to the volume of stock available for trading and to financial reporting.

The large American paper companies are all listed. Those which we follow reported 1959 sales aggregating $8,149,783,000.

Criteria for Judging P/E and Yield

There are many criteria which are used in judging a paper stock. The simplest is the "price/earnings ratio," and another is the "yield." The price/earnings is the result obtained by dividing the market price for a share of stock by the earnings per share. This is a measure of "investors' confidence." A high price/earnings indicates high investor confidence and a low price/earnings, the reverse. The progress of the industry and the investment status of its stocks can be judged by the changes in the price/earnings of its major companies.

Another criterion is the "yield," that is the per cent of the dividends received to the market price.

Ascertaining the Judgment of the Market

A rough rule for ascertaining the judgment of Wall Street on a given stock is that if the yield is high and the price/earnings low the issue may be judged to be on the speculative side. If the situation is reversed and the yield low with price/earnings high, one deduces that the Street feels that earnings will soon grow and that dividends will rise with increased earnings.

How does Wall Street register these market judgments? By the unrestricted operation of a free auction the judgment of investors is sifted out and tried in the fire of the market.

How do I as an analyst approach the problem? I have not time to discuss here all the factors to be considered but I will list some of them.

ECONOMIC FACTORS FOR ANALYSIS BASE

1. Relation of demand for paper to the business cycle.
2. Cyclical behavior of the different grades.
3. Grade patterns of growth.
4. Capacity and operating rate.
5. Prices.
6. Sources of raw material and their relation to products made and plant location.
7. Labor relations.
8. Research and development.

These are background data and their current position is of primary importance:

FOR AN INDIVIDUAL COMPANY WE CONSIDER

1. Grades made and their weighting in the company's sales.
2. Growth factors and cyclical behavior of each.
3. Plant location, equipment, and labor relations. Location related to product made and its market.
4. Raw material will determine location to a degree.
5. Research and development programs should be evaluated.
6. Plans for growth outside of the United States. Effect of "inner six" and "outer seven."

Last but not least, management itself must be evaluated. Is it competent? Is it moving in the right direction? And is it bringing along competent secondary management to take over when retirement plans hit its top producers? These are grave problems and they will require the best ability of any analyst in his evaluation of a paper company.

HISTORICAL PERSPECTIVE

To get the "feel" of the present attitude of investors it will be necessary to review some history. I doubt if many in this audience can remember the financial horrors of the 1930's. The paper industry felt the impact of the banking crisis and for the only time on record the industry, taken as a whole, was in the red.

LOUIS T. STEVENSON, Director of Paper Industry Div., Tucker, Anthony and R. L. Day, New York, N. Y.

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There have been and always will be differences in earning power, some companies above and others below the industry average. But from 1931 to 1935 inclusive the average net after taxes for the primary paper industry was in the red. Under these circumstances it can be well understood that the paper industry, with the exception of a very few companies, was in the dog house so far as Wall Street was concerned.

From 1936 to 1940 net *before* taxes averaged less than 5% on total assets employed. In this discussion I am using the percentage of net profits after taxes, to total assets, as a common denominator for comparing profitability at different periods. I recognize that the more customary ratios are net to sales and net to net worth, or common equity, but I believe that the ratio that I use gives a fairer comparison. It was not until the push of World War II and its rising demand and prices that sales rose as high as 70% of total assets (1940) when they should be about 90 to 100% for integrated mills.

Many of you will doubtless recall the wartime taxes and restrictions on production and prices but in spite of these the industry averaged net *after* taxes as a per cent of total assets:

5.74% in 1940	4.42% in 1943
7.24% in 1941	4.35% in 1944
4.98% in 1942	4.18% in 1945

Institutional Investors

At the close of the war institutional investors, that is investment trusts, insurance companies, banks and pension funds were still skeptical about earnings of the paper industry. Price earnings ratios were generally low as for example in 1948 we had:

	P/E
International Paper Co.	3.7
Scott Paper Co.	11.5
Kimberly-Clark	4.8
West Virginia	4.2

But beginning with 1946 the industry turned in greatly increased profit margins as follows, through 1956:

Net After Taxes as % of Total Assets

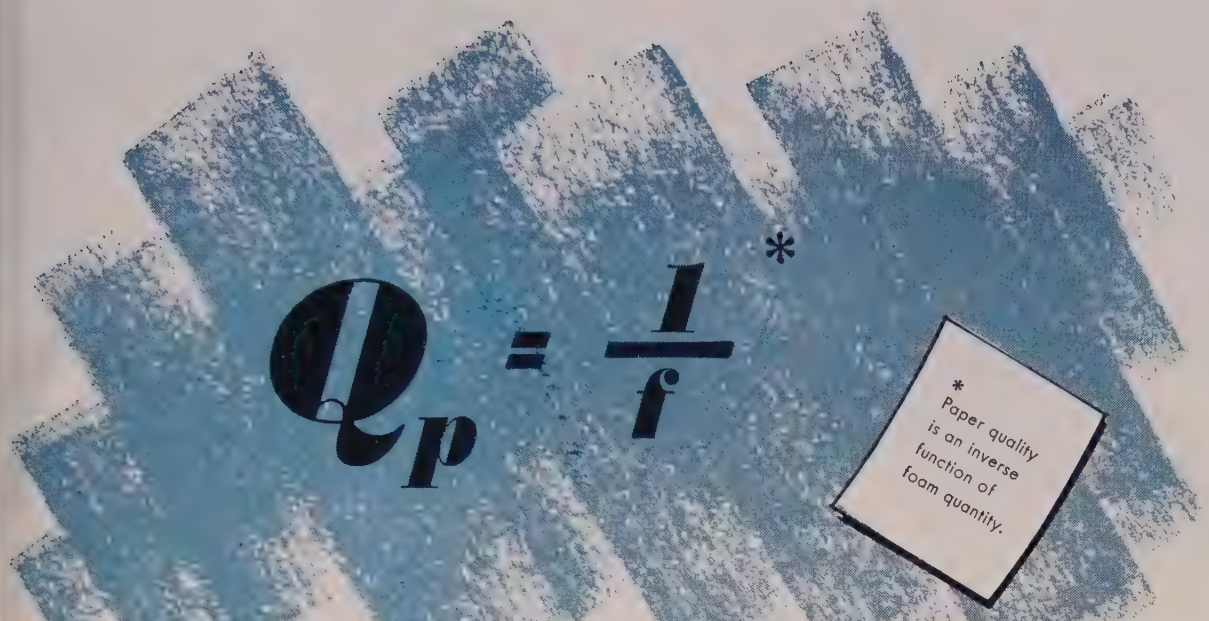
	Per cent		*Per cent*
1946	8.9	1953	7.7
1947	12.6	1954	7 8
1948	11.0	1955	9.0
1949	8.4	1956	8.3
1950	10.8	1957	6.7
1951	8.9	1958	5.6
1952	7.5	1959	6.5E

It will be noted that margins slipped in 1957 and 1958 and recovered slightly in 1959, last year.

Price earnings rose as follows:

	1952	*1956*	*Recent*
International Paper Co.	9	20	16
Scott Paper Co.	12	27	27
Kimberly-Clark	9	20	23
West Virginia	8	19	15

The 1956 P/E held substantially up to the first of this year and it seems more than likely that many investors expected a *continuance of the inflation* that



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with **Nalco 71-M**

Effective, easy-to-handle, and economical paper machine antifoam

Better Paper—Faster Production

If stock is trapped in the headbox by a mass of foam, it can't do much for sheet formation. Nor do bubbles on the wire add anything to the quality of your paper.

Such adverse conditions can easily be avoided, however – with Nalco 71-M, a hard-working paper machine antifoam. It is especially designed to improve paper formation by eliminating excess foam under the low pH conditions generally encountered in machine operations.

Nalco 71-M prevents floating stock in the headbox, so that stock which would otherwise be trapped in air bubbles is instead deposited on the sheet to give you better paper formation. On the wire, Nalco 71-M prevents formation of bubbles to eliminate pinholes in the finished paper.

Foam weakens the structure of paper, necessitating slower machine speeds and resulting in more frequent breakage and more down time. Nalco 71-M eliminates foam, allowing higher machine speeds with less down time.

While acting as an effective antifoam and defoamer, Nalco 71-M does not adversely affect either sizing or furnish. It has also been cleared by the U.S. Department of Health, Education, and Welfare, Food and Drug Administration, for use in the manufacture of paper and paperboard for food packaging.

Easy-to-handle and Economical

Shipped in liquid form, Nalco 71-M makes an instantaneous emulsion without stirring—even in water as hard as 400 ppm. Nalco 71-M emulsion is stable, too, and can be prepared in large quantities and stored for long periods of time.

Top-notch cost performance is another characteristic of Nalco 71-M—you can knock down more foam with less antifoam, if the antifoam is Nalco 71-M. In one field evaluation, for example, Nalco 71-M proved more economical to use than did live steam.

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As with all Nalco Chemicals, technical service from your Nalco field representative, backed by the experience and facilities of Nalco's laboratories, is yours with Nalco 71-M. Your Nalco representative can help you analyze your foam problems and find the most efficient application of Nalco's fine antifoams to solve them. For further information on Nalco 71-M, and the other Nalco antifoams made especially for the paper maker, call your local Nalco Representative or write directly to Nalco for details.

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had prevailed since 1940. The integrated paper companies with their large timberland holdings make an almost perfect hedge against inflation.

During the 1945–50 period the paper industry surprised much of the investing public by its earnings performance. Price earnings ratios rose sharply above the 1946 level. Many paper companies were included in the blue chip category. Institutional investors were buying "the papers" because they were "growth stocks." The volume was increasing steadily, and reasonably good profit margins were the rule.

But for some companies in 1960 earnings had slipped compared with the 1959 results. The situation is spotty because others have been able to raise their earnings. The bull market for stocks in general has turned into a bear market, with the Dow-Jones averages slipping from about 680 in January to around 570 in October of this year.

I believe that the readjustment was due to a large extent to the realization that inflationary influences had disappeared at least for the moment. In practically all industry there was a profit squeeze. Costs were rising and it became difficult if not impossible to pass them on in the form of price increases because of the abundances of supply. This was the case in steel, aluminum, and many other industries.

With but few exceptions our paper industry's price/-earnings ratios have generally moved down by the route of lower earnings and severe markdown of the prices for common stocks of many companies. The drop in the market reflects both lower earnings and lower price earnings ratios.

Many executives have been talking about "overcapacity" in the industry, blaming price weakness for their product on too much capacity. And yet the operating ratios of American Paper and Pulp Association and the National Paperboard Association show operations at over 90% of capacity week after week. Last year was a record year for production. So far this year we are ahead of last year except in the building paper and board grades. We are not like the steel industry or the automobile industry. We are making perishable, one-time use commodities from a renewable natural resource and our sales and markets are growing steadily. Investment managers have told me that either we should cut costs to fit our prices or top management should see to it that a satisfactory profit is forthcoming through proper pricing. That a number of companies are doing this stands on the record. Let us not drop back into the prewar II profit margins. That would be fatal to the future investment status of the paper industry.

DEPRECIATION RATES

Let me say here that there is a cost factor that is a deduction from profits now that was not generally present before the tax revision of 1954. That is the sum of the digits and the declining balance method for calculating depreciation charges. These increase costs but they also set aside tax free cash for additions to plant and equipment, which in the long run, benefit stockholders. These charges when applied to the much more expensive new equipment, help to raise costs appreciably. However, they also tend to make expansion programs self-liquidating out of cash flow.

FORWARD INTEGRATION

Another point that should be considered when thinking about profit margins is, that a number of primary paper manufacturing companies have acquired converters and, in some cases, paper merchants in recent years. This forward integration tends to reduce profit margins on sales. There apparently is also an unfortunate tendency for top management to consider the converting department as a means of getting business for the manufacturing end and to forget the profit on conversion in order to fill the paper machines.

These two factors, rising depreciation charges and forward integration into converting, tend to reduce profit margins and due allowance should be made for them when analyzing a given company. I am inclined to the belief that their influence on the overall primary industry reports is not very great, however.

Presented at the meeting of the Metropolitan District of the Empire State Section of TAPPI, held in New York, N. Y., Nov. 9, 1960.

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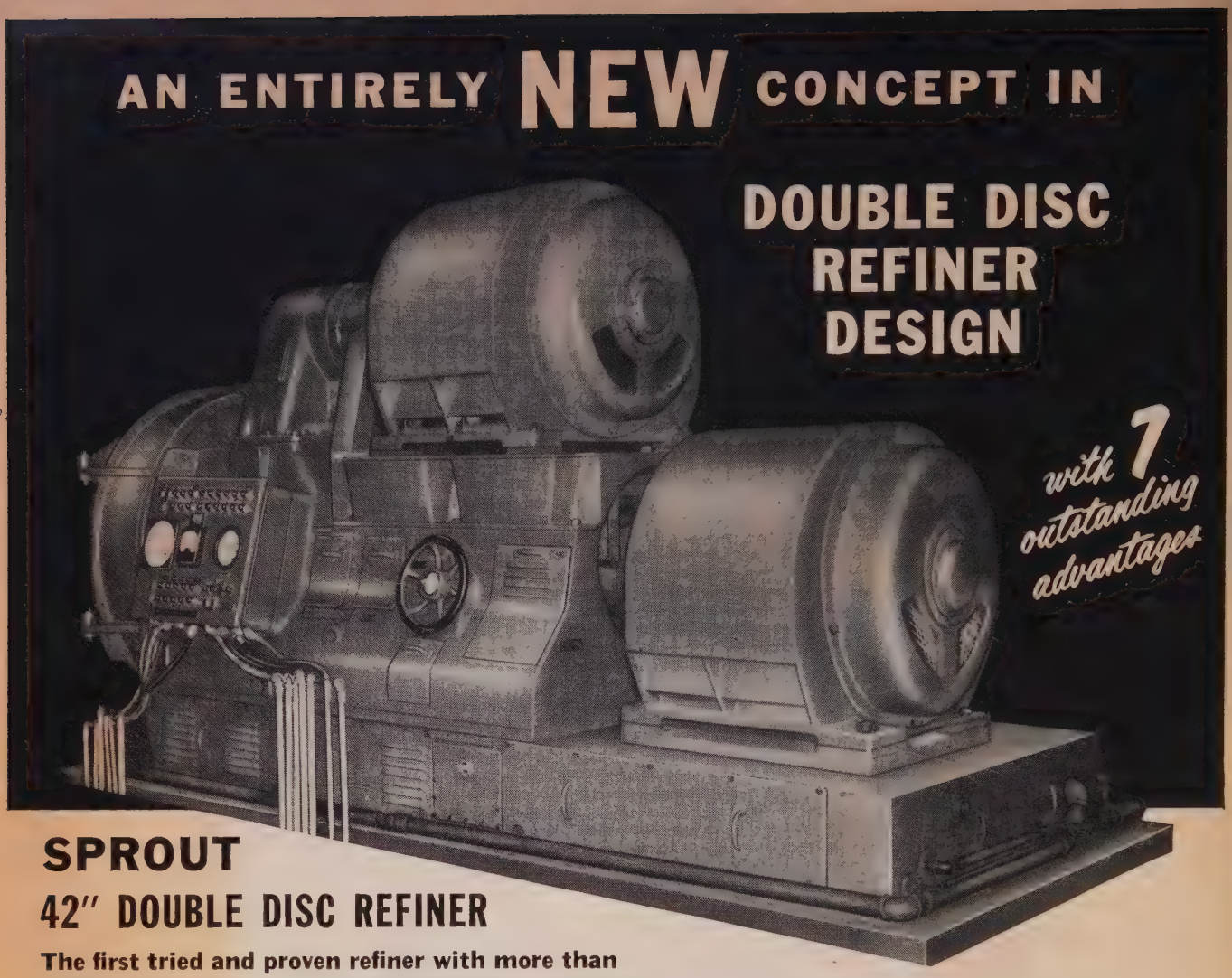

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4 HYDRAULIC PLATE POSITIONING – Disc refining pressures can be readily adjusted to the amount required for best quality and top production to suit the application.

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6 AUTOMATIC REFINER ADJUSTMENT—Once the plate gap is set, hydraulic controls take over to maintain automatic control. The refiner controls may be installed in a central control console if desired.

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Write for Bulletin 231

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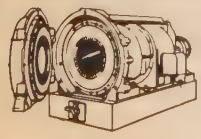
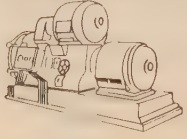
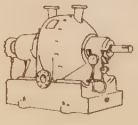
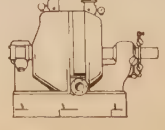


36-1 • REFINERS • 36-2

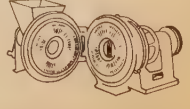


DOUBLE DISC REFINERS





20″-34″ • PRESSURIZED REFINERS • 42″



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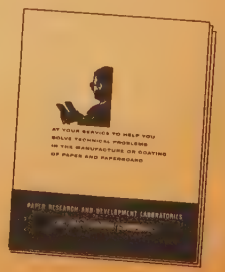

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The Story of the Kodak Red and Black Film Paper

CHARLES A. UPSON

Early in 1905 I learned as manager of the Niagara Paper Mill at Lockport, N. Y., that Eastman Kodak Co. was not entirely satisfied with the black paper used in their film spools.

I ascertained that the sensitized coating on the celluloid film in contact with black paper greatly shortened the life of the film so that in time sharp pictures were not obtained. Moreover, the black paper had some minute holes which caused specks in the picture.

To me these defects presented an intriguing problem, since I was greatly interested in the development and production of technical papers for various uses. At this time I was also a camera "hobbyist" and had my own dark room for developing glass and film pictures. This hobby required a so-called ruby light for vision in the dark room. I speak of this since the ruby light played an important part in my development of the red and black paper.

On one of my business trips to Rochester in January, 1905, I called on the purchasing manager of the Eastman Kodak Co. to ascertain more about the defects in their black spool paper and also the possibility of obtaining the specifications of the black paper.

I was not successful in obtaining the information or encouragement in my effort to improve the black paper. The purchasing manager plainly said to me "Young man, many older papermakers than you have tried to make us a better film and have failed, so I do not believe you could help us." He then added, "We are now buying the film paper of a mill that has given us about as uniform and good a paper as we have ever been able to obtain, therefore we will not make a change."

This was a discouraging interview but it did not dampen my ambition to do some really successful research work to produce a better film paper. I began at once to find a strong fiber that would not have a reaction with the sensitized celluloid film. I also began making a study to remove all impurities in the process of making the black paper.

After making many laboratory experiments and also changes in the process machinery, I added to our equipment a filtration plant to obtain pure and clean water. Having these improvements, I then had a run of the proposed black paper made. It appeared to be very good and in testing it was quite neutral, uniform in caliber, and strong.

I took several dozen 12 × 12 inch sheets and presented them to the purchasing manager for testing. However my interview with him did not create any interest. Upon returning home the thought came to me that perhaps I could make more progress if I sent samples of the film paper to one of the Kodak chemists whose name had been given me. With this in mind I made another trip to Rochester and was successful in having him make a few hasty tests of the film paper that I gave him. However, he was doubtful that the Kodak Co. would consider a change in their source of supply.

I continued my work in trying to further improve the film paper. One night in experimenting in my home "dark room" the thought came to me. Why not make a duplex paper with one side black and the other ruby red? The idea at the time was that the red paper on one side might be helpful in blanking out any so-called "pin holes" and at the same time be quite distinctive for the film rolls.

Perhaps I should mention here that it so happened that I installed a cylinder making machine in the base ment under another paper machine on the floor above. This made it possible to bring a sheet of paper from the machine below and combine it with a sheet of paper above. This combination of two sheets produced many unusual duplex paper products. I think this combination of two sheets of paper was the first in the United States.

A run of this proposed red and black paper was made and it appeared to be a real success. It met all the tests that we could make.

Three large rolls of this duplex paper were shipped to the Kodak Co. together with a descriptive letter of all the outstanding factors to be gained in approving the new duplex red and black paper.

About three weeks later a letter was received from the Kodak Co. stating that they had tested the red and black paper and that they would like to send one of their research men to Lockport to discuss the new duplex film paper.

This was a very encouraging turn in the relationship with the Kodak Co. The chemist did come to the mill and we had a long discussion and we learned fully of their interest in this new paper. We quoted them a price which was approved and we were given an order for a ton for further testing.

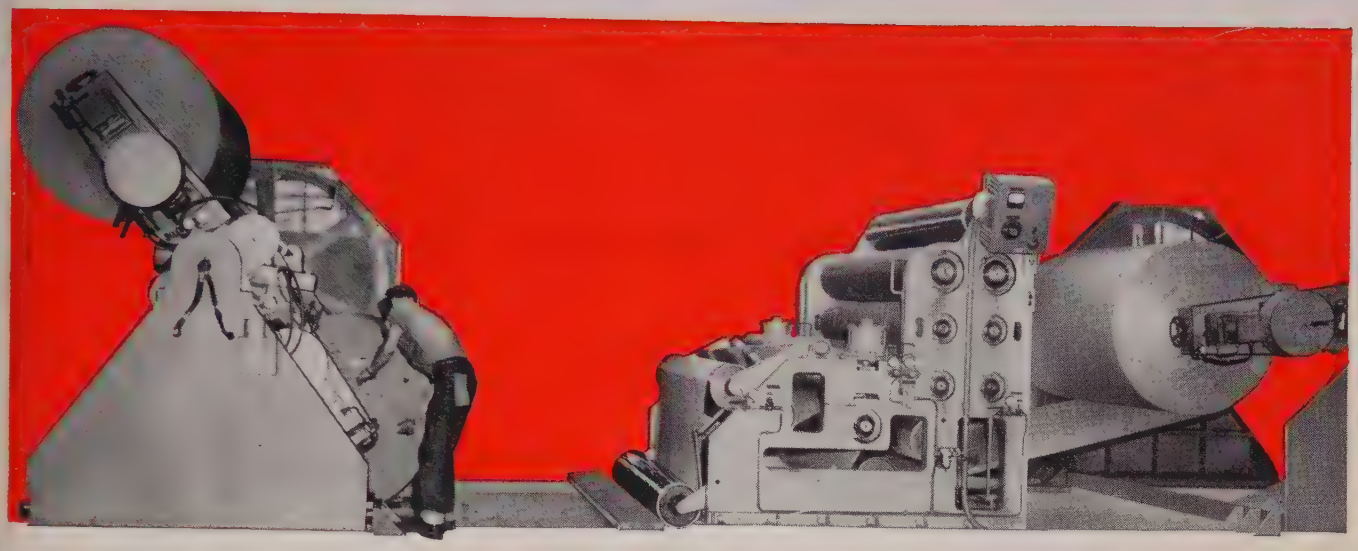
A month passed and then I received a phone call asking me to come to Rochester for a conference. I went to the conference and to my surprise George Eastman, president of the Kodak Co., Frank Lovejoy, vice-president, and two others, including the chief chemist, greeted me.

The conference lasted about an hour and it indicated that the Kodak Co. was definitely adopting my duplex red and black film paper. To me it was a very gratifying and profitable conclusion. The Kodak Co. accepted the quotation of the Niagara Paper Mills. The Niagara Paper Mill in turn agreed not to make any red and black film for any other camera or film concern.

It might be interesting to add that Mr. Eastman talked very little. However, after the meeting he asked me if I liked the manufacture of paper and said that he was glad to meet a young man who had accomplished so much for them in producing a film paper that enhanced their business.

CHARLES A. UPSON, Lockport, N. Y.

100" WEB WIDTH



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The Niagara Paper Mill shipped the Kodak Co. many carloads while I was manager of the mill and we never received a complaint, which was very pleasing to our organization.

I resigned from the Niagara Mills a little over a year and a half after the signing of the Kodak contract. The very capable mill superintendent, Ralph Snell, and others of the staff also resigned. This resulted in the new management losing the Kodak business since the new Niagara Paper Mills group were unable to maintain the quality of the red and black film paper.

This event produced a serious situation for the Kodak Co. It lead them to build their own paper mill to produce the red and black paper. Mr. Lovejoy, the vice-president, invited me to come to Rochester to discuss with him the plans and equipment, for which he paid me generously.

The Kodak Paper Mill venture required extraordinary planning to produce a chemically neutral, strong, and opaque duplex paper. The Kodak Paper Mill is one of the finest paper mills in existence and I might add that is just one of the factors that proves that Eastman Kodak products are superior.

In closing let me say it was gratifying to me that my red and black film paper fully warranted my claims although it brought me no personal financial profit.

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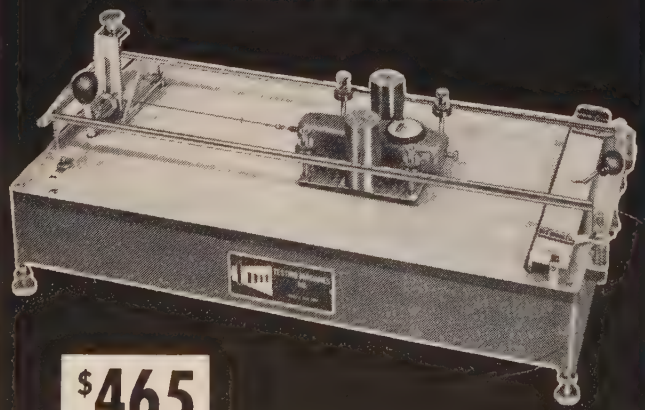

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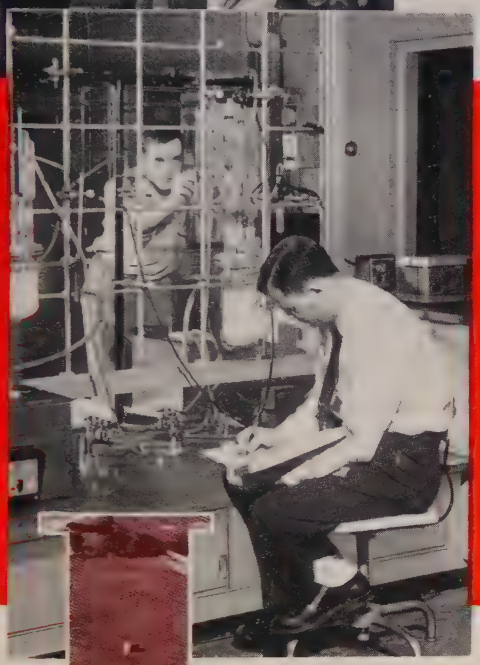

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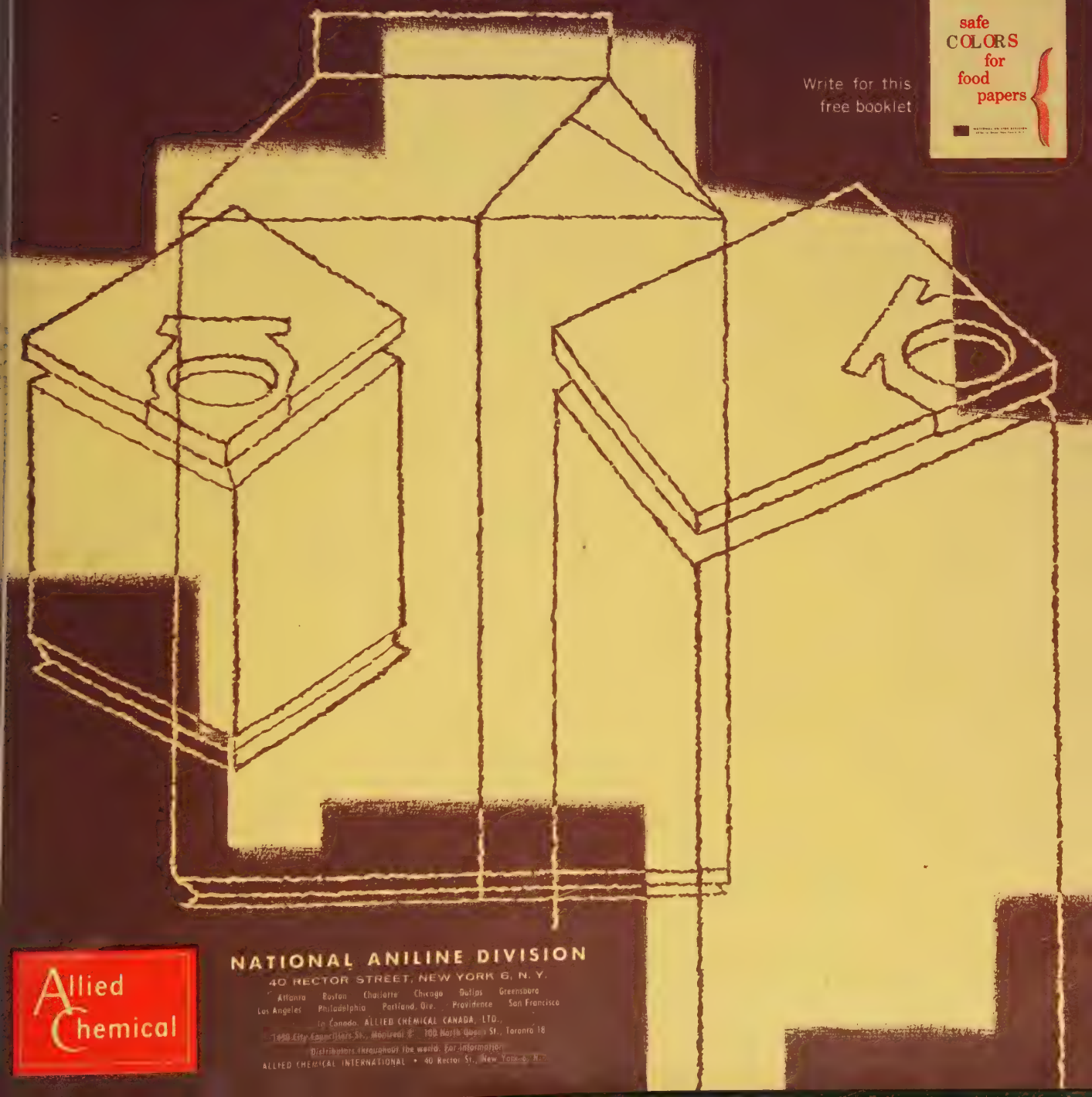

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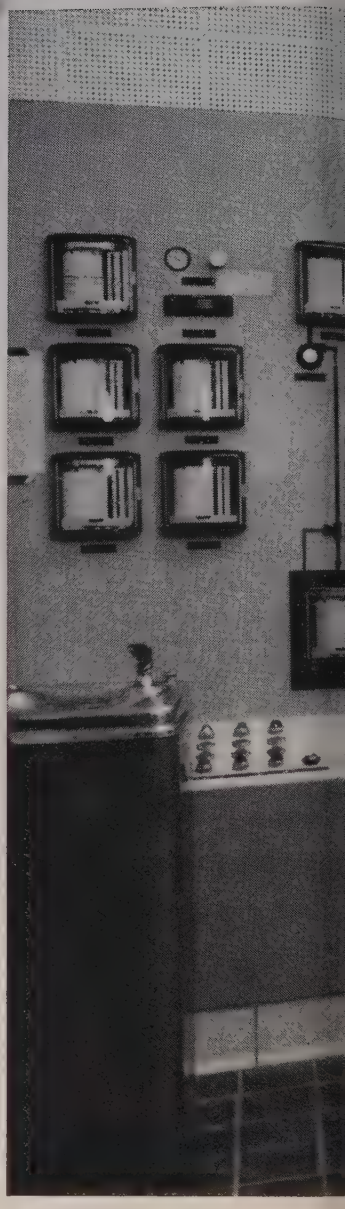
MEAD'S NEW CHILLICOTHE BLEACH PLANT FULLY CONTROLLED BY TAYLOR

The Mead Corporation has installed the latest Taylor TRANSCOPE® Instruments in the new four-stage bleach plant at its Chillicothe, Ohio Division. Designed by Mead engineers to provide fully automated operation, the plant is a complex of controlling, recording and measuring instruments, some of which are shown here. The main control panel, built by Taylor, connects 62 process control stations and dozens of essential process indicating and recording instruments.

This ultra-modern graphic control panel enables one man to operate the entire bleach plant. A similiar Taylor graphic panel is now being supplied for Mead's brown stock washing and screening system at the same plant.



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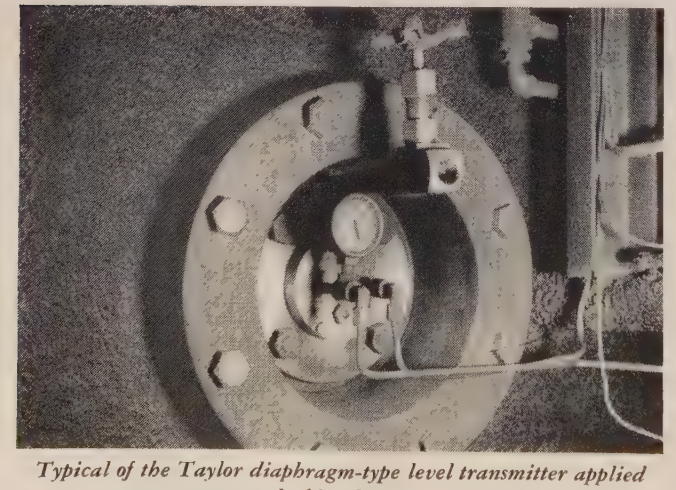
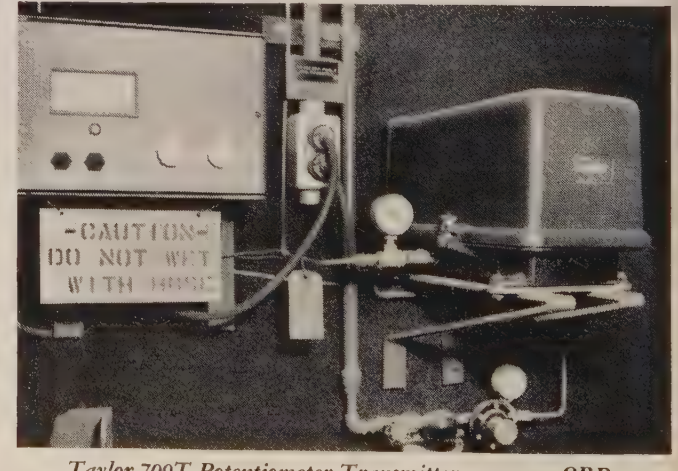
If you would like to know more about the application of Taylor TRANSCOPE *instruments to your processes, ask your Taylor Field Engineer or write Taylor Instrument Companies, Rochester, N.Y., or Toronto, Ont.*



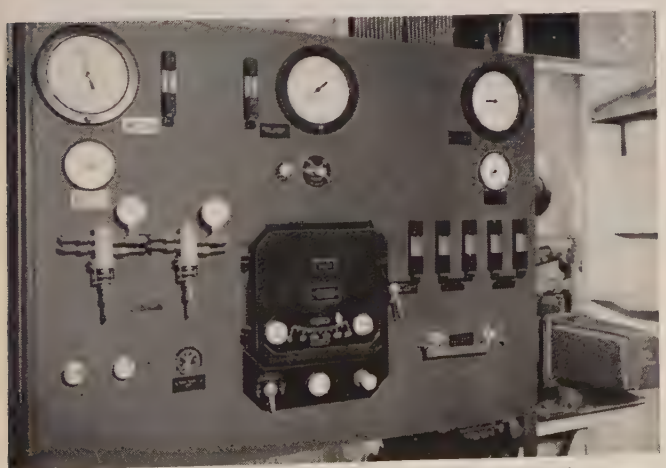
Typical of the Taylor diaphragm-type level transmitter applied to the bleach towers.



Taylor 700T Potentiometer Transmitter measures ORP on chlorine feed to the chlorination stage.

Taylor Instruments

One man supervises the complete operation of the new 4-stage bleach plant from this Taylor Graphic Control Panel at The Mead Corporation's Chillicothe Division.



Taylor also controls the chilled water supply in the chlorine dioxide manufacturing system.

Taylor Volumetric Load Measuring Element measures weight of chlorine storage tank.

MEAN ACCURACY FIRST

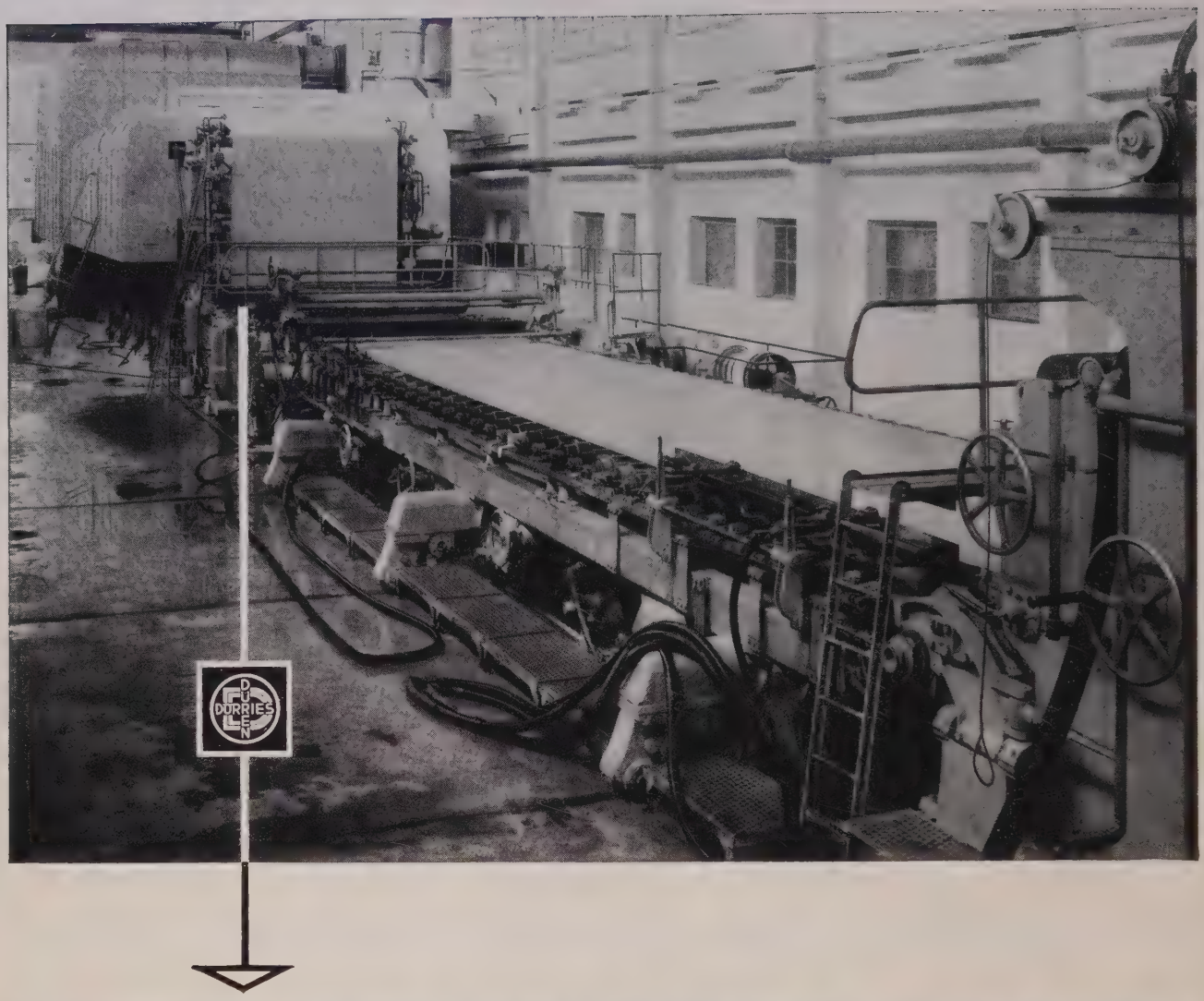


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Illustration courtesy Continental Can Company

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RHOPLEX all-acrylic emulsion, used in the coating on this page, produced a printing surface unique in its smoothness, flexibility, ink receptivity and high pick resistance. Freedom from odor of RHOPLEX-base coatings extends their usefulness in a wide variety of papers and paperboard.

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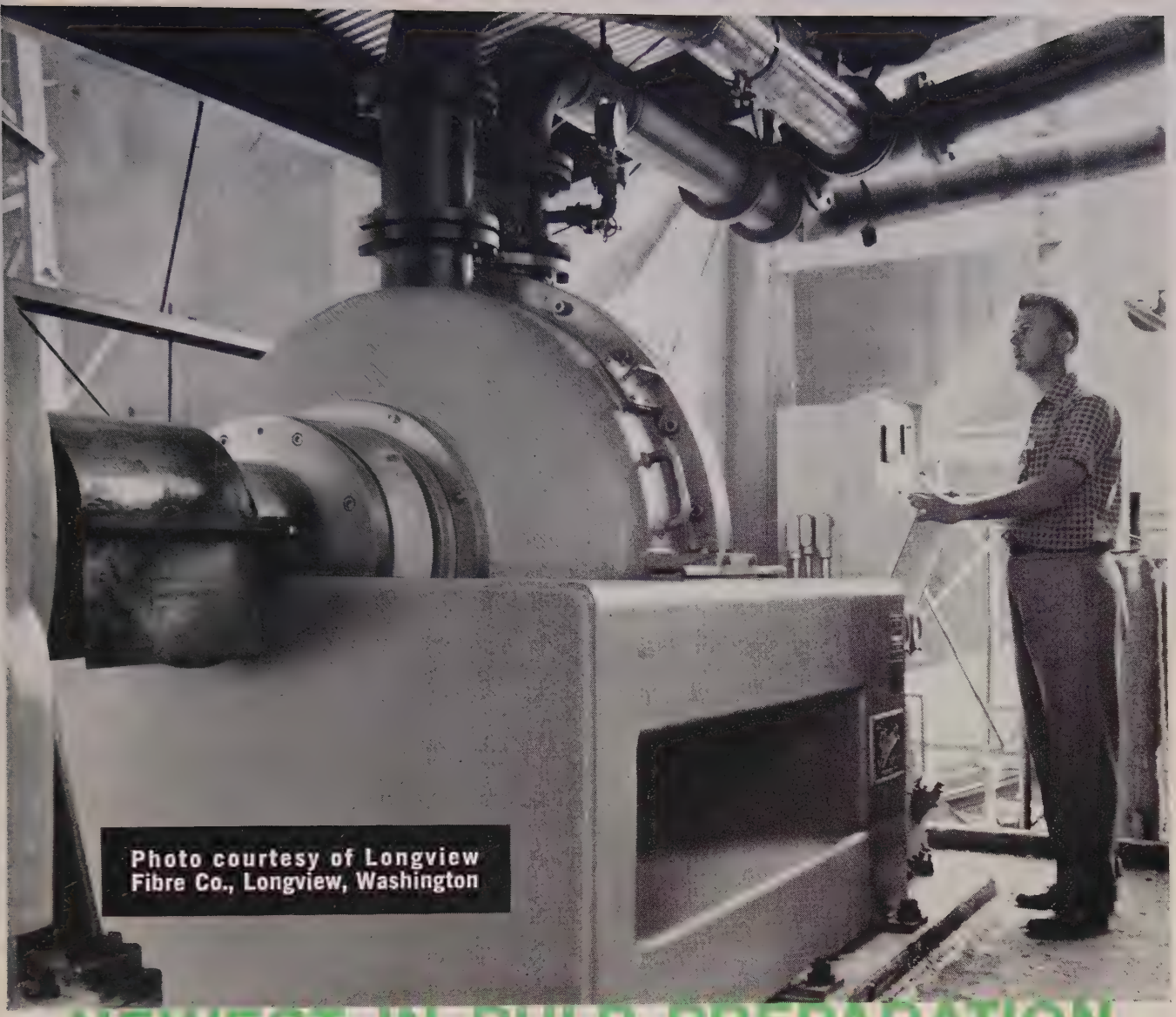

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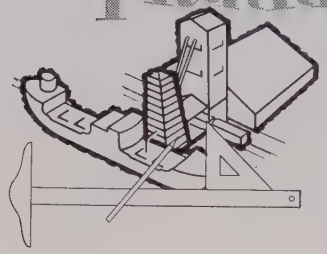

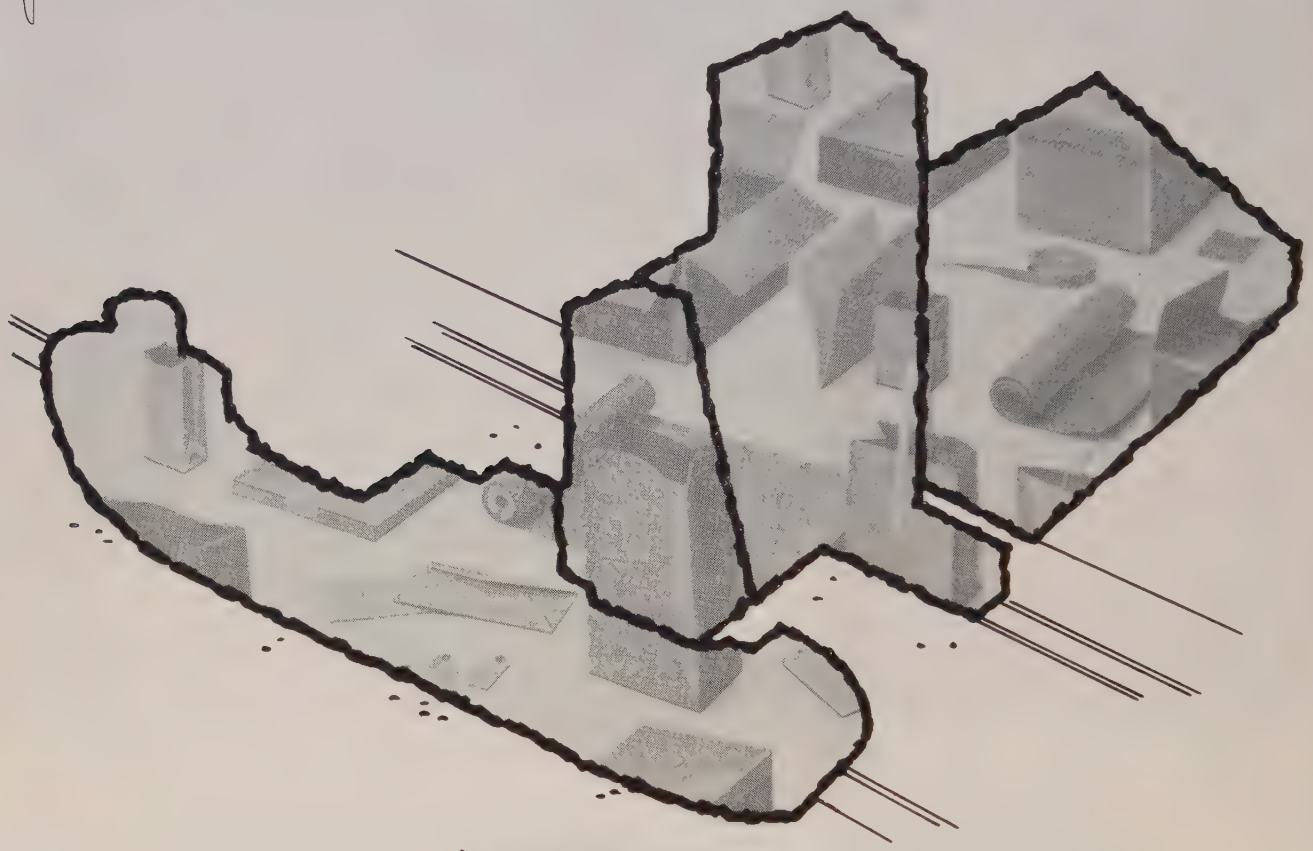

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use **Penford Gum**

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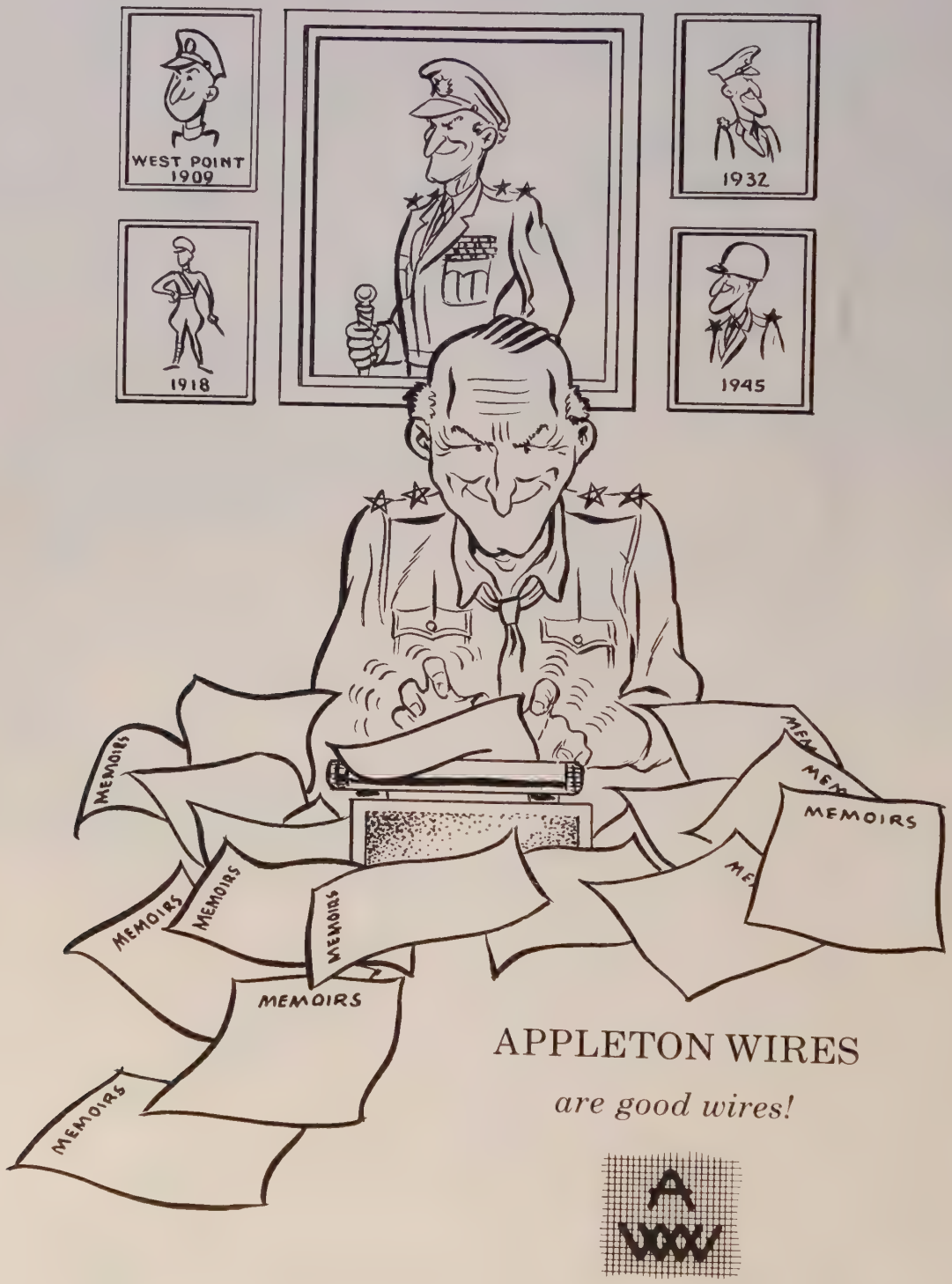

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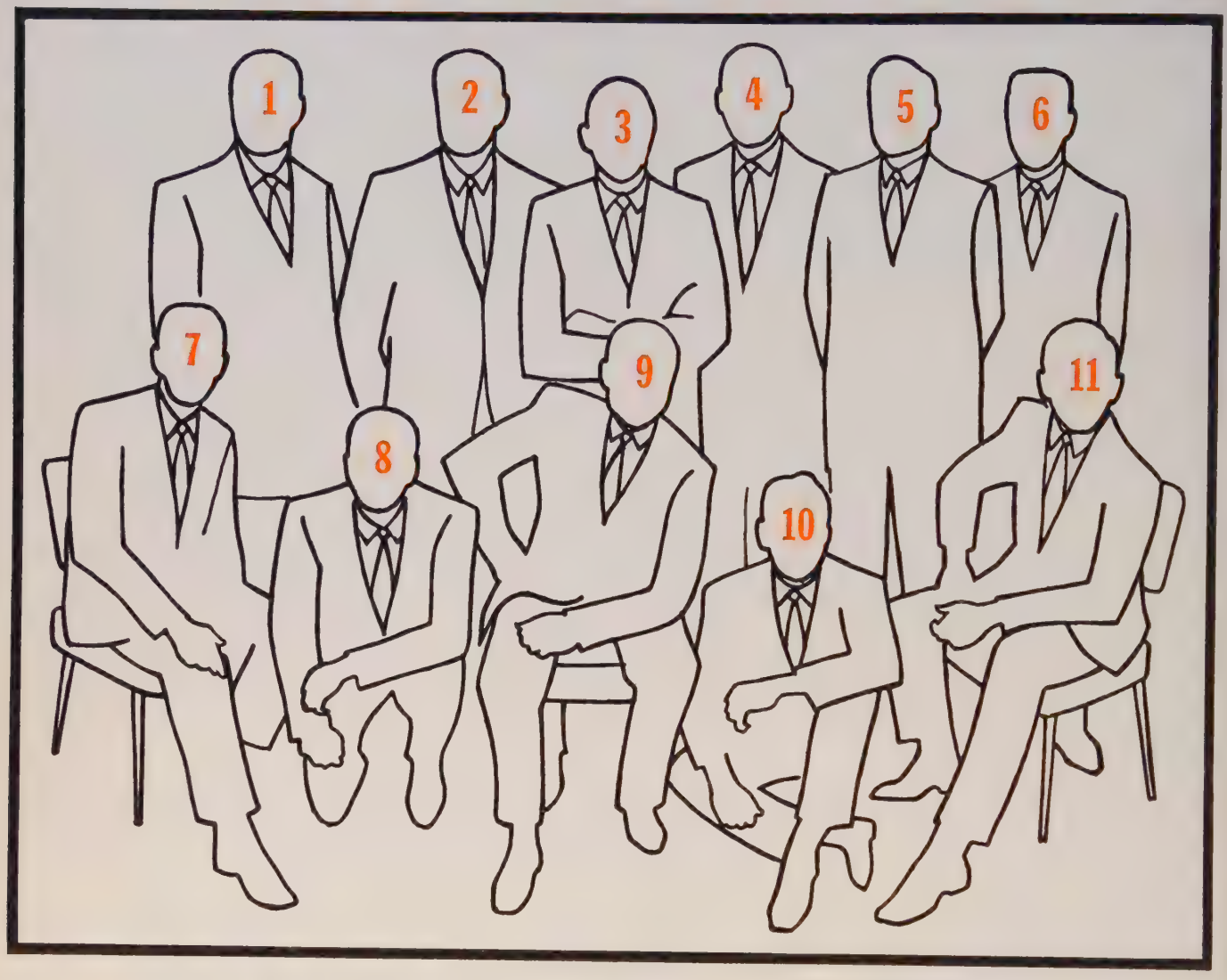

Group photo of 11 Allis-Chalmers paper industry specialists

too busy to pose

. . . but that's the way we work at Allis-Chalmers. Attention to customer service makes it hard to get these 11 specialists together for picture taking. Emphasis on giving prompt, practical solutions to the mechanical and electrical problems of our customers has given us a breadth of experience that no other manufacturer can offer! Whether you are looking for information on a single piece of equipment or on a complete process, contact your A-C representative or write the Industrial Systems Dept., **Allis-Chalmers,** Milwaukee 1, Wis.

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3 **L. C. Vogel** Paper Stock Pumps

4 **H. A. Wright** Electrical Controls

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Data on the Betz experienced approach to microbiological control in paper mills is contained in Bulletin 592. Write for a copy, today.

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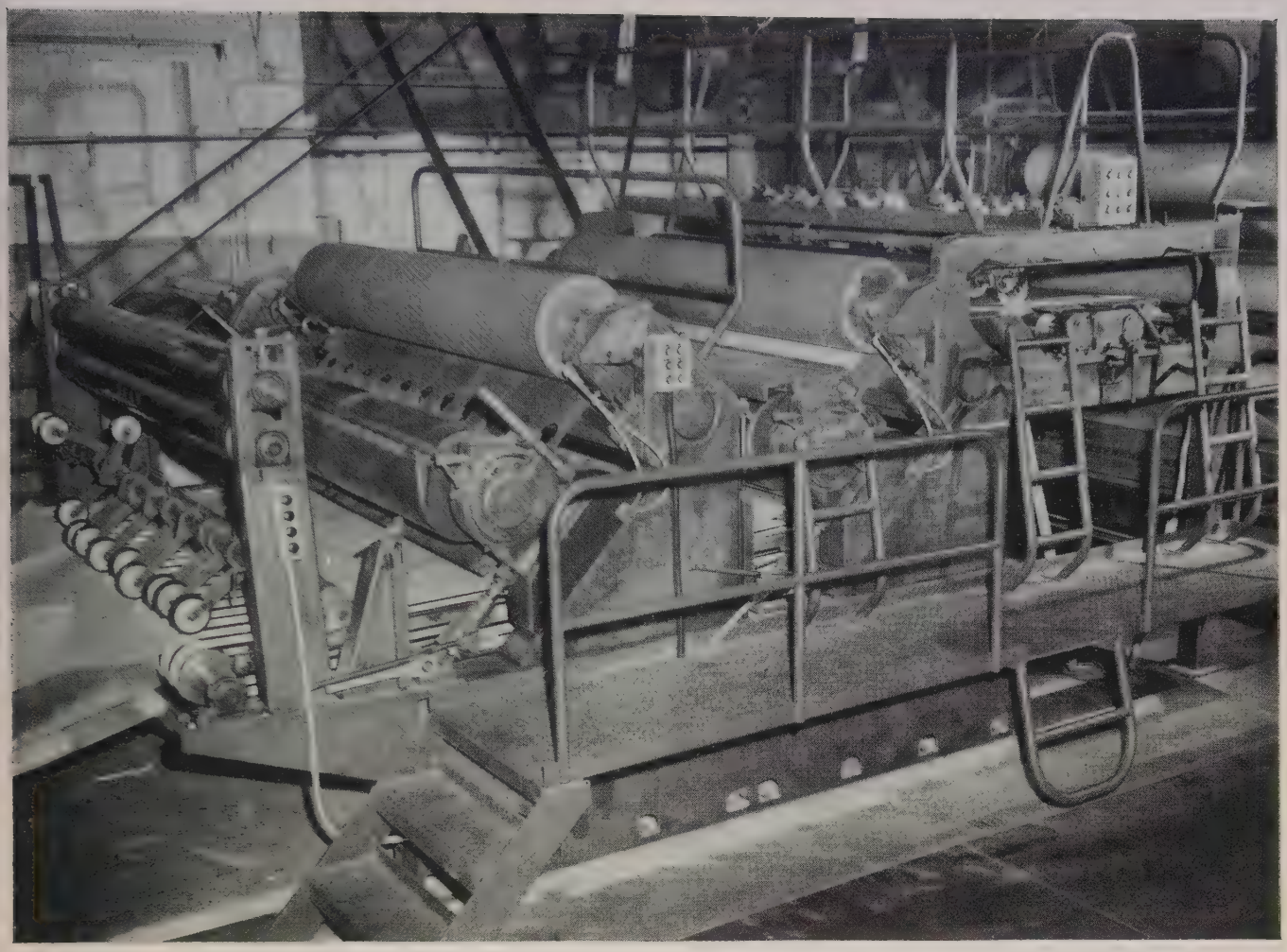

Packaging Corporation of America, Central Fibre Products Division., Hutchinson, Kansas

New Beloit Duplex Cutter and Slitter

The cutter pictured above is a completely new Beloit design. You will find that its thoroughly proven components, rugged and dependable, contribute to new high standards of production efficiency. Outstanding features are listed at right.

Look to Beloit Eastern Corporation to furnish you with the finest in finished product processing equipment:

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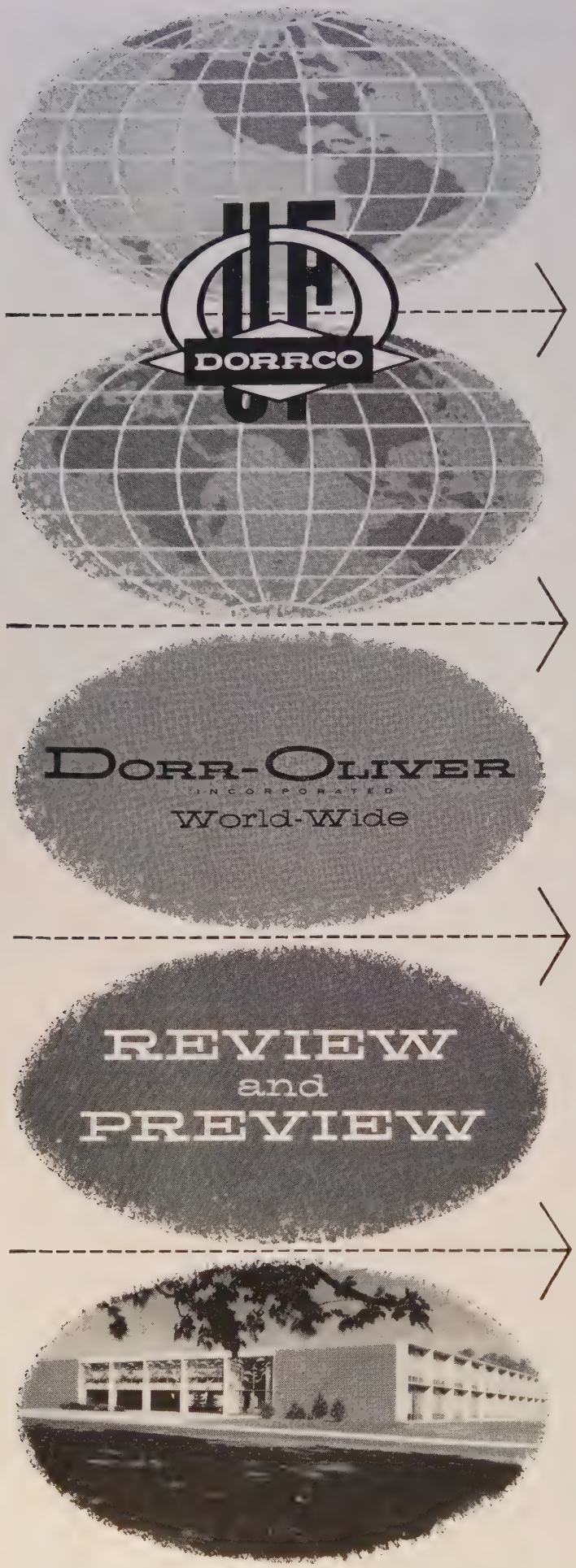

1960 has been a year of significant technical gain and measurable improvement in overall incoming business volume. In technology, a selective concentration of our development effort has begun to show results. Some of these new units and processes currently being marketed are mentioned below. Others, several of which show considerable commercial as well as technical promise, are nearing fruition and should be available during 1961. Progress in basic product standardization and redesign has also played a significant part in our technical advance and will have a substantial effect on our ability to serve our customers.

Virtually every segment of our worldwide operations has contributed to the increased volume of new business with an unusual degree of activity on exceptionally large projects apparent in many areas of the world. This overall gain has been reflected in somewhat higher billings and profits but a substantial increase in backlog has been the primary result.

METALLURGICAL—During the past year, the first installation of the new Dorr-Oliver DSM Heavy Media System went into operation on iron ore beneficiation in Minnesota. This process utilizes a DorrClone unit as the heavy media separatory vessel and other newly developed D-O units in the media cleaning circuit. As compared with conventional practice the new system provides better media cleaning, improved recovery and grade of ore and sharply reduces magnetite losses.

Included in the flowsheet is the D-O SiphonSizer, a hydraulic classifier operating on the hindered settling principle. In limited use for several years, this unit is now being applied in the metallurgical and non-metallics fields on both a commercial and experimental basis where sharper classification is of benefit.

For water conservation, one of the largest center pier Dorr Thickeners to be built in recent years is soon to go into operation for a major copper producer. Overall diameter of this unit is 375 feet.

NON-METALLICS—The continued installation of varied D-O equipment in wet process cement plants throughout the world has reflected the expansion of this industry, particularly in South America. It is interesting to note that in this latter area several Dorr Slurry Mixers in the 100 foot dia. range are being installed. These are among the largest ever fabricated.

A new development of significance in the cement industry was the introduction of the 270° DSM Screen —a unit which has increased grinding mill capacity when used for closed-circuiting or scalping. Considerable operating experience is available from several installations in Australia and Europe.

Substantial flowsheet improvement in phosphate rock beneficiation and coal washing has resulted from the application of sharper classification in Dorrco Hydroscillators and Sizers. The Oliver Horizontal Filter and the Dorrco FluoSolids System have been successfully operated in combination.

FOOD & PHARMACEUTICAL—In food and pharmaceutical industries, highly efficient separations coupled with economies in operating costs and space continue to attract processors to Dorr-Oliver centrifugal equipment. In the starch industry, for example, Merco Centrifuges, Mercone Screening Centrifuges and DorrClone Systems were selected in various combinations for expansions, modernizations and new plant facilities in Argentina, Mexico, the Philippines, South Africa, Uruguay and the United States.

Food processors also discovered the advantages of the DSM Screen and began to apply them to various dewatering jobs, such as germ separation, fibre washing and pulp removal from waste process waters. A new rotary vacuum filter of plastic construction, with interesting cost savings over stainless steel, performed well on clarification of fruit juices. Small diameter DorrClones in porcelain construction also solved speck and seed removal problems in various juice lines.

A leading manufacturer of new, high protein products for food and industrial use has utilized D-O equipment and services in developing new, continuous processes.

CHEMICAL—The versatile Oliver Horizontal Filter was applied to the washing and dewatering of a number of granular chemical products. A major breakthrough in the thermal drying of nitrocellulose by a special design of the Oliver Horizontal Filter resulted in substantial reduction in operating costs with a significant advance in safety. A multiple and repeat installation

of Horizontal Filters for phosphoric acid production was ordered late in 1960 from a major producer.

The newer unit operation of centrifugation continued to prove its potential in the field. Typical examples of its application are the successful use of Mercone and DorrClone units for carbon removal from paraffin oil and of a Merco Centrifuge for the removal of impurities from phosphorus.

PETROLEUM & PETROCHEMICALS—A new development of importance during 1960 was the application of the Mercone Centrifuge to the removal of liquids from polymer crumbs. One of the most exciting developments was the success of a special 'clamshell' DorrClone for catalyst removal from cat-cracker-fractionator bottoms. This solves a long standing refinery problem and should have wide application.

The Synrub filter is still an accepted standard in the processing of synthetic rubber both in the United States and elsewhere in the world. As an example, South America's first synthetic rubber plant, which was built during the year in Brazil employed a multiple D-O Synrub filter installation.

In the field of petroleum production, a principal D-O activity continued to be the use of DorrClone desanding and degritting units in water injection and drill mud conditioning. These are also now being applied to degritting of crudes.

The high demand for paraxylene has been partially solved by the application of a Merco Centrifuge separating paraxylene from a xylene stream at —80° F. Higher recoveries are achieved than ever before.

PULP & PAPER—The continuing increase in paper demand in every part of the world has resulted in the sale of brownstock washing, recausticizing and pulp bleaching systems both in the United States and abroad. Filters, pumps and sedimentation equipment have also been in demand for both pulp processing and such accessory services as water and waste treatment.

A significant advance in pulp bleaching by chlorine dioxide, the D-O concentric bleaching tower was made available broadly to the industry this year. The first of these towers has completed a year of highly successful operation in Idaho; the second will be in operation early this year.

Close cooperation and attention resulted in the supply of substantially all equipment for additional brownstock washing and bleaching sections at the newest mill in the Northwest.

MUNICIPAL AND INDUSTRIAL WASTE TREATMENT—Interest was extremely high in activated sludge treatment and applicable new D-O developments continued to gain momentum. The D-O Aerator was applied to the treatment of combined strong domestic and industrial wastes in municipal plants. Late in the year, the D-O Inka Aerator was introduced. Developed in Sweden and widely used in Europe, it combines high oxygen absorption rates with low power requirements and can be used most effectively on low BOD waste.

Programs conducted in the field on Densludge thickening and digestion were reported in detail during the year. One major city expects to save $6,000,000 in its current plant construction program through the use of this technique. In another interesting application, the Sultzer Disintegrator has improved digester performance in one large municipal plant when used to grind the thickened sludge.

Successful demonstrations of the RSR Clarifier proved the efficiency of this new unit for separating high volatile return sludge from waste sludge. Also, the use of the SpiroVortex System for the activated sludge process was further exemplified by a new installation in California.

In the area of sewage sludge dewatering, Dorr-Oliver Plastic Filters proved successful at Westport, Conn., and Paw Paw, Mich., while new filters of conventional design were installed at Harrisburg, Penna., and Marshall, Miss.

WATER TREATMENT—An outstanding event of the year in water treatment was the completion of the five-year construction program at Philadelphia's ultra-modern 423 mgd Torresdale plant for which D-O supplied four Dorrco Flocculators, and four Dorr Squarex Clarifiers. Another outstanding municipal water treatment plant is under construction by the Metropolitan Water District of Southern California. This plant will incorporate sixteen Dorr Squarex Clarifiers.

In the area of recent developments, a new Dorrco PeriFilter System will shortly go into operation at a southern city to treat 4.0 million gallons a day, and successful pilot plant demonstrations of an improved lime sludge handling method were carried out in several mid western cities. An increasing number of DorrClone units for desanding well water are being installed to protect meters and valves in industrial and municipal water supply systems.

Worldwide activity in new industrial plant construction, particularly in the pulp and paper field, has resulted in much activity in the application of both Hydro-Treators and conventional pre-treatment units to industrial water treatment.

PROJECT ENGINEERING — Much of the activity in this sector of D-O operations was provided by the rapidly expanding fertilizer industry. This included plants for the beneficiation of phosphate rock and for the production of phosphoric acid, ammonium phosphate, triple superphosphate and complete granular fertilizers. Typical of this area of activity are two phosphoric acid plants now being designed by D-O in Florida on a turnkey basis. A plant of unusual interest is being designed to recover ilmenite from heavy, mineral bearing sands for the ultimate production of titanium. D-O engineering includes the processing equipment, all auxiliary facilities and structures.

Other engineering projects include beneficiation of iron and copper ores, recovery of copper scrap, and facilities in such diverse fields as the pulp and paper industry, nitrocellulose manufacture, and starch production. Geographically, projects are underway in Africa, Brazil, England, France, Germany, India, Ireland, Japan, Jordan, Mexico and Yugoslavia as well as the United States.

FLUOSOLIDS SYSTEMS—1960 was a year of unusual activity involving both new and thoroughly demonstrated applications of fluid techniques. Plants for drying fine coal and both the drying and calcination of varied metallic and non-metallic ores continue to be in demand and contributed substantially to overall volume.

In the realm of the new and unusual—an important plastics plant went into production during the year utilizing a Dorrco FluoSolids System to dry the product Other similar applications are in the development stage. Another unusual application involving the roasting of copper concentrates for partial removal of sulphur prior to smelting will go into operation early in 1961. Also in 1960 a major chemical manufacturer ordered a third FluoSolids Reactor for processing food additives.

Of particular interest is a 200 ton per day lime plant scheduled for completion in mid 1961 in Florida. It is being completely designed and engineered by D-O on a turnkey basis with FluoSolids Reactors utilized in both the key steps of limestone drying and calcination.

SUGAR—Two new D-O developments were introduced to the Cane Sugar industry during 1960.

The D-O Rapi-Floc System introduces a controlled flocculation step before filtering of cane mud on a modified Oliver-Campbell Filter. The second development involved the application of DSM Screens to juice screening, with improved clarification and filtration reported as a result.

Throughout the year there has been a continuing demand for RapiDorr Clarifiers, Oliver-Campbell Filters and other standard Dorr-Oliver equipment for both new and expanded cane sugar mills, with the Middle East, Far East, Africa and Latin America particularly active.

We have several challenges ahead. We must provide our customers with even greater technical competence and service. We must continue to improve our profit structure to provide the income we need for continued technical and corporate growth in the future. We must provide growth and stability by adding to our product lines and areas of activity.

Through the dedicated efforts of our staff around the world we have made substantial progress in these areas during the past year. I am confident that this progress will continue and accelerate in the months ahead.

L. R. Boling
President

December 1, 1960

OVER 50 Goulds centrifugal pumps play a vital role in the recently completed expansion program of Union Bag-Camp Paper Corporation at Savannah, Ga. Pumps range in size from the 1½″ x 2″ stainless steel color system supply and transfer pumps to the 24″ x 24″ primary cleaner pump and are utilized for water, white water, stock, various liquors—practically every application encountered in modern paper mill practice. Services covered include pumps for the machine, blow tank, cleaners, showers, high-density storage refiners and many other applications.

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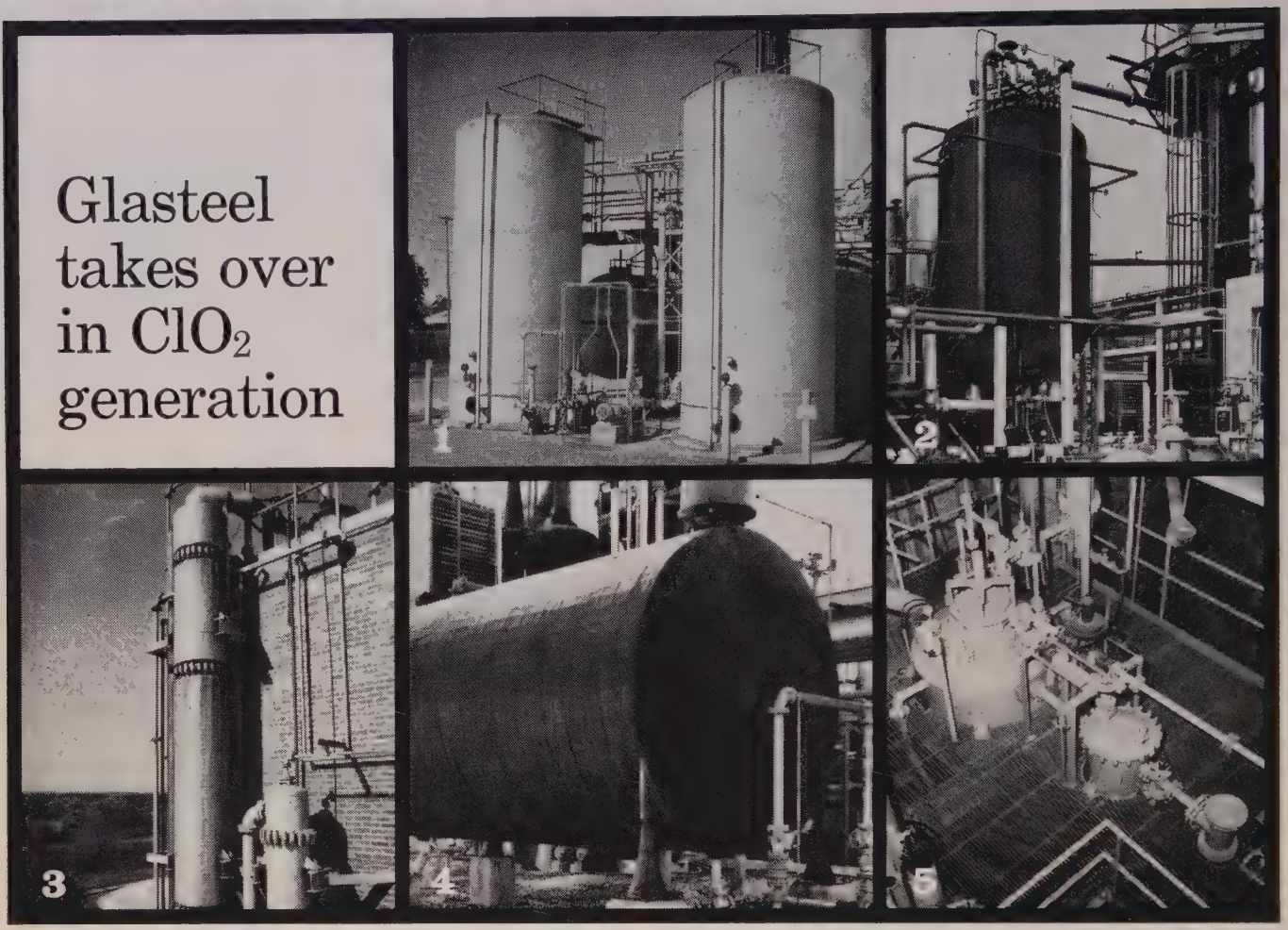

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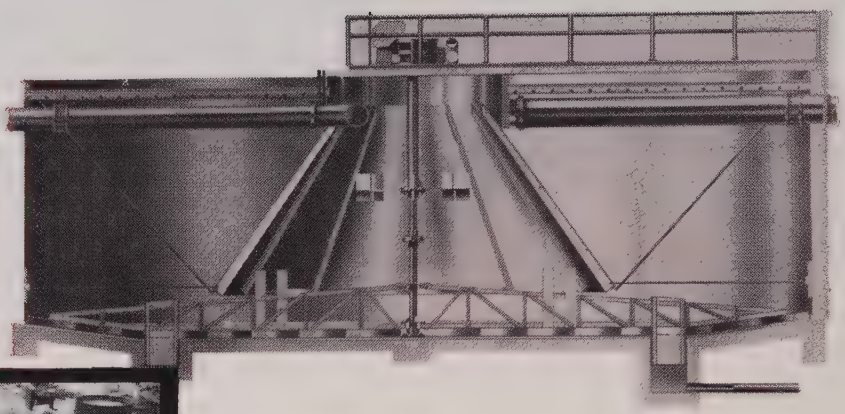

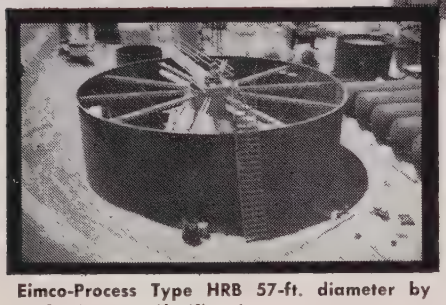

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Aspects on the Bleaching of High Yield Pulps

H. W. GIERTZ

The problem of bleaching high-yield pulps is to obtain high brightness (>80 G.E.) without dissolving the lignin. This cannot be performed with ordinary bleaching agents as chlorine, hypochlorite, and chlorine dioxide, because these agents form colored substances with the lignin, which has to be attacked further. A final high brightness cannot be achieved before all lignin is dissolved. Peroxides have a specific decoloring action on wood without reacting with the lignin and forming colored substances. Chlorates are also said to bleach without appreciable lignin losses. In the present work these agents have been used for bleaching high-yield neutral sulfite and cold soda pulps. It was found that sodium chlorate is not a suitable "surface" bleaching agent because chlorite, chlorine dioxide, and some chlorine are formed. During bleaching a heavy discoloration takes place and a final high brightness can only be obtained by dissolving a major portion of the lignin. With peroxides some promising results were obtained. It was found that pulps having been discolored during the pulping operation were impossible to bleach without dissolving all the lignin. If the cooking could be performed under such conditions that no extra color was formed, the "surface" bleaching was quite good. By cooking birchwood with a bisulfite cooking liquor to a yield of about 85% and bleaching with 2 to 3% peroxide and 1% sodium hyposulfite, a bleached pulp of 81 G.E. and a yield of more than 80% was obtained.

In the last 10 years an important development has taken place in high yield pulping. Semichemical neutral sulfite (NSSC) pulping is today an established technique, cold soda pulping is increasing in importance, and very much interest is paid to the possibilities of making strong pulps at high yield with the pH 4 bisulfite process. With these and other processes it is possible to cover the whole yield range from 90 to 60% with a variety of pulps. The strength properties of these are closely dependent on their yield. An important fact is, however, that these high-yield figures are related to unbleached pulp. The next step of development, therefore will be to convert these pulps to bleached ones while maintaining high yield. Such bleaching has commonly been called "surface bleaching" and its main object is to dissolve or decolorize colored matter in the pulp without substantial loss of material. As the single way of getting high-yield pulps is to keep at least a part of the lignin in the pulp, surface bleaching means in reality decoloration without dissolution of the lignin. "Lignin-preserving bleaching" seems, therefore, to be a more adequate expression and will be used in this paper.

The light-yellow or brownish color of wood is due to certain unspecified pigments in very low concentration. Native lignin is supposed to be colorless. In the pulping reactions, however, lignin easily becomes colored which most likely can be referred to lignin condensation reactions. As condensed lignin is not always highly colored (*1*), a more marked discoloration may be due to the reaction of lignin with minor constituents of the wood or the cooking liquor, such a furfural (*2*). More detailed knowledge about the chemical nature of the substances causing the color of the pulp is desirable.

Lignin-preserving bleaching has successfully been adopted to groundwood. Both sodium- and hydrogen peroxide are known to be good brightening agents, for mechanical pulp and bleaching takes place without any noticeable loss of substance. In combination with a final-hydrosulfite stage a brightness of 76 to 78% G.E., might be obtained. At this brightness level, the pulp still has a yellow tone. To be "white" and to be of real interest for ordinary fine papers the pulp should have a somewhat higher brightness. In the present paper the minimum brightness requirement has been set at about 80% G.E. The usual bleaching agents are the ordinary chlorine compounds, as elemental chlorine, hypochlorite, and chlorine dioxide. Peroxides have already been mentioned. Recently activated chlorate has also been suggested as a bleaching agent specially suitable for high-yield pulps.

OXIDIZING AGENTS

Chlorine Compounds

Chlorine. The technique of bleaching NSSC pulps with chlorination. alkali extraction and a final brightening stage with hypochlorite is well known. Chlorination, however, always involves the formation of orange-colored chlorolignin compounds, which, due to their nature, turn brown in alkali. At the same time the lignin becomes water soluble, which of course is the main object of the chlorination treatment. It is therefore meaningless to use chlorine with the aim of decolorizing the lignin without dissolving it, and it is well-known fact that ordinary bleaching, including a chlorination stage, always results in a serious decrease in yield and gives a lignin-free pulp.

Hypochlorite. When bleaching prebleached pulps, hypochlorite has a brightening action and the final product becomes lignin-free. When starting with hypochlorite on unbleached pulps, and specially on high-yield pulps which, by definition, have a high lignin content, the pulp becomes reddish-brown, which obviously is due to the same type of reaction as during chlorination. By prolonged bleaching the color of the pulp becomes yellow with a brightness of about 70% G.E. Bleach consumption is about 10% as available chlorine and the bleaching is accompanied by a certain drop in yield. If, however, the brightness has to be increased to 80% or higher, the bleach consumption is much higher, the pulp is seriously attacked and the decrease in yield corresponds to that of ordinary bleaching including chlorination.

Chlorine Dioxide. This compound reacts very rapidly with lignin and the products first formed are most probably colored. They are, however, attacked

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further and broken down to colorless, soluble substances. Furthermore, during chlorine dioxide bleaching the chlorine dioxide is primarily reduced to chlorous acid, hypochlorous acid, and elemental chlorine. At least the two last-mentioned compounds will also react rapidly with the lignin forming the typical colored chlorolignins. This explains why it is also impossible with chlorine dioxide to make white pulps without dissolving all the lignin.

In common with these three chlorine compounds is their very rapid reaction with lignin. Therefore, they cannot be used as selective bleaching agents for colored products other than lignin. To obtain a white pulp, the colored chlorolignin has to be broken down, and there is no end to this reaction until all the lignin has been attacked and dissolved. This means a substantial loss in yield and, consequently, these bleaching agents are of no interest for high yield bleaching.

Activated Chlorate. Marpillero (*3*) has recently suggested bleaching with sodium chlorate, activated with certain catalysts as vanadium, molybdenum and manganese salts. This ACL bleaching can either be used as an ordinary brightness bleaching stage, substituting hypochlorite or chlorine dioxide, or as prebleaching of high-yield pulps. According to Marpillero (*4*) a fully bleached hardwood pulp in high yield can be obtained in the following way:

1. The chips (unbarked chestnut) are softened in a sodium hydroxide solution (4 to 5% by volume) for 4 to 5 hr. at 70 to 90°C. The alkali consumption is 8 to 10% and the yield between 70 and 80%.
2. The refined pulp is treated with ACL at 65 to 75°C. for 4 to 6 hr. The consumption of chlorate is about 6 to 10%.
3. Final bleaching with hypochlorite and peroxide giving a brightness of 80 to 88% G.E.

The overall yield is estimated at 60 to 65% and consequently ACL bleaching might be of interest for the production of bleached high-yield pulps.

Based on the experience collected from peroxide bleaching, which will be dealt with in the next section, both a cold soda and a high yield, bisulfite birch pulp, was selected for the following studies on ACL bleaching.

In order to determine suitable bleaching conditions, the amount of ACL (5 to 20%), pH (0.15 to 6), temperature (20 to 95°C.) and reaction time were varied systematically. The ACL treatment was followed by hypochlorite bleaching, and in some cases also by peroxide bleaching.

No combination gave results of technical interest. It was found that the chlorate consumption was low and that the ACL treatment had only a minor influence on the final bleaching result. Generally, brightness decreased during the ACL treatment and in some experiments better results were obtained without the ACL.

In a subsequent investigation the probable mechanism of chlorate bleaching was studied, using formaldehyde as the reducing agent. It could be shown that chlorine dioxide was formed in large amounts, and also chlorine if the pH of the solution was below 2. The rate of these reactions was tripled by the addition of a catalyst.

It was concluded that chlorate does not react in a specific way with the colored matter of the unbleached pulp. As both chlorine and chlorine dioxide are intermediate reduction stages, the same colored chlorolignins must be formed as when these agents are used separately, and consequently a fully bleached product can be obtained only after all the lignin has been dissolved.

Peroxides

As known from groundwood bleaching sodium- and hydrogen peroxide are selective bleaching agents, decolorizing the colored wood substances without forming colored lignin products. Peroxides, therefore, seem to be of greatest interest for bleaching high yield pulps.

Spruce Bisulfite Pulp. A bisulfite pulp was prepared with a sodium-base bisulfite cooking liquor containing 1.2% free, and 1.9% combined SO_2. The total amount of SO_2 was 12.6% calculated on ovendry wood. The temperature was raised to 170°C. in 3 hr. and kept there for another 3 hr. The initial liquor pH was 5.9 (20°C.), decreasing during the cooking to 3.6. The pulp was easy to defibrate and showed the following characteristics: yield 63%; TAPPI permanganate number 38, and brightness 54% Hunter.

This pulp can be considered to be a normal bisulfite pulp, even if today it might be possible to obtain a brighter pulp by cooking at lower temperature and somewhat lower pH.

The pulp was bleached with sodium peroxide in several steps and the bleaching conditions such as the amount of sodium peroxide (0.9 to 2.5%), temperature (20 to 70°C.), pulp consistency (20 to 40%) and bleaching time were varied.

In all cases the bleaching resulted in a lowering of the brightness to 45 to 50% Hunter. In several experiments, however, a negligible brightening effect was observed at the very beginning of the bleaching.

According to Schröter (*5*) a prebleach with small amounts of hypochlorite followed by peroxide bleaching gives good results on ordinary acid sulfite pulps. Such a combination of hypochlorite (2.5%) or chlorination (5%) with a finishing peroxide stage was also tried but resulted in a brightness of 40 to 42% Hunter. The only way of getting a noticeable increase in brightness (65 to 70% Hunter) was to add 15 to 20% chlorine in the first stage. Such bleaching, however, involves a more or less complete dissolution of the lignin and is of no interest for the present investigation.

Knowing that peroxides have the ability to decolorize the original colored substances in wood, the conclusion was drawn that during bisulfite cooking new colored substances are formed which are stable to peroxides. Most likely this colored matter is formed within the lignin molecules by condensation, a reaction which is known to extend the lignin absorption curve to the blue part of the visible spectrum. If this hypothesis is correct, the next conclusion is that high-yield pulps, which have to be bleached without loss in yield, must be produced under such conditions that the lignin does not give rise to colored products. Then, if the color originates from certain units or parts of the lignin molecule only, these have to be broken down to get a colorless pulp, and it seems very improbable that a bleaching agent may be found which degrades such

colored units without attacking the native ones. An exception to this generalization will be dealt with later.

Birch Semichemical Bisulfite Pulp. The only way, known to the author, of digesting wood under technically acceptable conditions without getting discoloration of the product is to cook with a bisulfite cooking liquor to a very high yield. It is of great importance that the pH be around 5 and not 7 or higher as in NSSC-cooking and that the digestion is stopped at a yield above 80%. At a yield of 75% or lower the formation of colored matter seems to be unavoidable. Being a light-colored hardwood, birch is particularly suitable for this kind of cooking. At this high-yield level the cooked chips have, of course, to be defibrated in some kind of refiner.

The birch pulp used in this study was cooked with a sodium-base liquor containing 1.1% bound, and 0.4% free SO_2. The total amount of SO_2 was 7% of the wood and of this only 2.3% was consumed during cooking. The chips were well impregnated at 105°C. and the cook performed at 140°C. for 3 hr. The pulp was obtained in 87% yield having a TAPPI permanganate number of 59 and a brightness of 67% Hunter.

In order to define suitable bleaching conditions, the amount of sodium peroxide (2 to 5%), alkalinity after addition of sulfuric acid (0.5 to 1.4% NaOH), amount of silicate (0 to 5%), temperature (2 to 70°C.), and reaction time were varied systematically. The amount of magnesium sulfate (0.5%) and pulp consistency (40%) were kept constant. Optimum bleaching conditions were found to be 2 to 3% sodium peroxide, 1% free sodium hydroxide, 2% sodium silicate, and a bleaching temperature and reaction time of 20 to 40°C. and 6 to 2 hr., respectively. These conditions are very much the same as those for ordinary groundwood bleaching. The brightness obtained was 78.5% Hunter at 20°C. and 77% at 40°C.

By adding an extra treatment with 1% sodium hyposulfite (5% consistency, 20°C. 20 min.) the brightness increased from 77 to 81% Hunter.

This type of bleaching is performed without any appreciable loss in yield (0 to 2%) and the bleached pulp is obtained, therefore, in a yield of about 85%. This indicates that the bleached pulp must be high in lignin content, and obviously the bleaching process adopted has been of the typical lignin-preserving type.

The very high unbleached yield was a prerequisite for the successful bleaching but as a consequence the papermaking properties of the pulp are poor. The pulp is extremely difficult to beat. After 4000 revolutions in the PFI beater, which corresponds to normal kraft pulp beating, the tensile strength equals that of groundwood, the tear factor is 30 and the burst strength and double folds, negligible. The opacity, however, is high (s' about 380). An interesting observation is that opacity does not decrease with beating but is kept fairly constant. This shows that this kind of pulp is extremely free and is not "hydrated" by beating. It should be classified as a typical filler pulp.

All sulfite pulps with a high lignin content, both bisulfite and ordinary acid ones, have a strong tendency to acquire a pink color caused by air oxidation. This reaction is specially dominant for birch pulps and is much stronger at yields below 75% than above 80%. The chromofore causing this reddening is supposed to be of the stilbene quinone type (*6*) and its leucoform to be formed during sulfite cooking.

The above-mentioned high-yield birch pulp was allowed to redden and on storage the red color changed into a grayish brown, which is typical for this color reaction. When bleaching the gray pulp with peroxide, as mentioned above, the same brightness was obtained as for the fresh pulp. It was concluded that peroxide destroys the lignin chromofore in question without attacking the lignin proper.

REDUCING AGENTS

Hydrosulfites

Many SO_2-compounds have been tried for groundwood bleaching, the most important of which are sodium- and zinc hydrosulfite. From a theoretical point of view these agents are of greatest interest because they have a decolorizing action without attacking the lignin. Their brightening effect, however, seems to be rather limited and is lower than that of peroxides. Today much interest is paid to the combination of peroxide and hydrosulfite bleaching.

CONCLUSIONS

There are two important factors to be considered by lignin preserving bleaching of high-yield pulps.

1. The pulping process must be performed under such conditions that the lignin does not become colored.
2. The actual bleaching agent must be able to destroy or decolorize the colored matter of the pulp without reacting with the lignin.

Lignin condensation reactions are the most likely cause of the decoloration taking place during the cooking process, both in sulfite and sulfate cooking. Condensed parts can only be decolorized by total or at least extensive degradation. It seems extremely improbable that a bleaching agent would be found having such a selective reactivity that it would react with the condensed portions of the lignin while leaving the native units unattacked. There is no bleaching agent known today having such extraordinary properties.

Decoloration through reddening is an exception. This reaction takes place over certain specific groups in the lignin which may be destroyed, for instance, by peroxide, without further reaction with the lignin proper.

Among technical bleaching agents all chlorine compounds, i.e., chlorine, hypochlorite, chlorine dioxide, chlorite and activated chlorate, are not suitable for lignin-preserving bleaching because they form in one way or another colored chlorolignin compounds. Owing to their ability to degrade colored matter without attacking lignin, peroxides are suitable for high-yield bleaching. Reducing agents and especially sodium- or zinc hydrosulfite, fulfill the same requirements but are less active than peroxides. A combination of both gives the best results known today.

It is possible to produce a birch pulp in a yield of about 85% and with a brightness above 80% G.E. by bisulfite cooking, refining, and bleaching in two stages with peroxide and hydrosulfite. The pulp is a filler pulp, having very low paper strength and high opacity.

The cardinal point in lignin-preserving bleaching is thus to prevent lignin decoloration by performing the cook under more suitable conditions.

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Egyptian *Phragmites communis* L. as a Pulp Source

M. A. EL-TARABOULSI

Experimental cooks were made on *Phragmites communis* (L.) of the Edku Lake, Lower Egypt, by the soda, kraft, neutral sulfite processes, and the pulps analyzed chemically and tested for physical strength properties. The results indicated the suitability of using the reed as a pulp source. The optimum results were obtained with a kraft cook using 14.2% NaOH and 3.5% Na_2S, and alkali cooks using 17.7 to 20.7% NaOH. For comparison work, the data were compared with soda and kraft (Egyptian) rice straw pulps. The results indicated the superiority of the reed pulps, as far as yields and strength properties are concerned, to that of rice straw. Reed-kraft wood pulp blends (50 : 50 mixtures that were beaten separately) showed an overall much improved folding endurance, and a slight lowering in bursting strength than the arithmetical mean of the components. Following this study, plant run trials were carried out on reed-kraft wood pulp blends at the National Paper Co., Alexandria (for the first time) and proved to be successful. Running the reed pulp at the proper load through a continuous beater was capable of developing the strength properties of the reed. The reed is now supplementing the rice straw as a pulp source in the paper industry in Egypt.

The possibilities of fibrous agricultural residues as a source of papermaking pulp for the production of fine papers are becoming more apparent and of increasing interest to the pulp and paper industry. The urgent need for the utilization of agricultural residues in paper manufacture is a necessity in many countries, for example, in Egypt, which is demonstrating a growth in literacy in recent years and which has no natural supplies of soft- and hardwoods. A list of available agricultural residues in Egypt is shown in Table I.

Table I. Available Agricultural Residues for the Paper Industry in Egypt: Average for 1952

Raw material	*Annual production, tons*
Wheat straw	1,812,000
Rice straw	481,000
Barley hay	132,000
Cotton stalks	1,970,000
Maize stalks	2,350,000
Millet stalks	640,000
Sugarcane bagasse	358,000
Flax stalks	18,000
Papyrus stalks	15,000
Phragmites communis reeds[a]	(30,000)

[a] Figures on actual production of the reeds are not available, and the probable annual production is about 30,000 tons.

Table I shows that nearly all the stated agricultural residues can serve as suitable materials for the production of pulp. However, economically, not all these raw materials can be used since the price of wheat straw is prohibitive (about $36 per ton) and is needed for cattle feed. Cotton stalks are being used mainly as fuel by the farmers and the problem of collecting the surplus, if any, will raise a serious question. Rice straw, in particular, is attractive since it is available in fairly abundant quantities at a price of about $9 per ton, and is used now in increasing amounts for making bleached and unbleached straw board, corrugating paper and other low grade papers. Specially cooked, screened and bleached rice straw pulps will be used, also, in this country in the near future in the making of writing and printing paper.

Table II. Approximate Chemical Analysis of *Phragmites communis*[a]

Determination	Phragmites communis (L.)	*Rice straw*[b]
Moisture, %	7.45	...
Ash, %	4.96	18.3
Ether extractives, %	0.79	0.7
Alcohol-benzene (1:2) extractives, %	4.83	5.4
Cold-water extractives, %	2.25	...
Total extractives, %	7.87	...
Lignin (corrected for ash), %	20.82	11.8
Alpha-cellulose, %	44.75	38.3
Pentosans, %	22.75	31.6

[a] All values except moisture are on ovendry basis.
[b] The values for rice straw (*9*) are given for comparison.

Of special interest of the stated agricultural residue in Table I is *Phragmites communis*. This reed grows annually in sufficient amounts in relatively small areas to warrant its use, if found suitable, as a possible source of pulp. It is of interest to note that the reed grows, partly, in Edku Lake, Lower Egypt, which is within a short transportation distance from the major pulp and paper mill in Egypt, and is a fairly inexpensive raw material, costing about $15 a ton. An extensive study was thus deemed necessary in order to find the suitability of this locally available, inexpensive raw material for the pulp and paper industry. Several studies were carried out on the various species of *Phragmites* (*1–6*), and this paper reports the results of evaluating *Phragmites communis* (L.), grown in Egypt, by the soda, kraft, and neutral sulfite processes, together with a report on plant run trials on reed-kraft wood pulp blends.

RAW MATERIAL

The reed from the 1957 crop was collected from Edku Lake and was left to air-dry. The reed was about 8 to

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Table III. Laboratory Pulping of *Phragmites* and Rice Straw[a]

Cook no.	Material	Cooking conditions: Chemicals: NaOH, %	Na2S, %	Na2SO3, %	Liq.: solid Ratio.	Temp., °C.	Time, hr.	Pulp yield, %	Chemical analysis: Ash, %	Pentosan, %	Lignin, %	Alpha cellulose %	KmNO4 no.	Physical constants at (or near) maximum bursting strength: Beating time of °S.-R. min.	freeness, ml.	Basis weight g.s.m.	Burst p.s.i.	Tensile, Kg./15 mm. width	Double fold, Schopper
									Soda Cooks										
1	*Phragmites*	16.2	...	...	5:1	150	3	50.7	1.8	23.5	9.1	72.3	22.8	65	510	70	29	5.5	166
2	*Phragmites*	17.7	...	...	5:1	150	3	49.6	1.6	21.4	5.8	76.1	21.4	70	420	68	37	7.5	464
3	*Phragmites*	19.2	...	...	5:1	150	3	47.3	1.7	21.2	4.7	74.7	20.2	50	430	68	39	7.1	607
4	*Phragmites*	20.7	...	...	5:1	150	3	46.2	1.8	21.1	2.7	79.2	18.1	50	490	61	34	6.9	462
5	*Phragmites*	21.9	...	...	5:1	150	3	45.7	1.8	19.0	3.1	80.3	17.0	45	520	70	43	7.2	614
6	Rice straw[a]	12.0	...	...	7:1	170	2	42.2	17.8	29.0	4.5	...	11.7	...	500	65	36	6.3	110
									Kraft Cooks										
7	*Phragmites*	12.1	4.1	...	5:1	150	3	49.8	...	21.2	5.9	69.7	22.2	45	455	70	40	7.1	447
8	*Phragmites*	14.2	3.5	...	5:1	150	3	50.7	...	20.8	4.32	74.1	17.2	40	450	72	46	8.5	672
9	*Phragmites*	12.5	6.7	...	5:1	150	3	45.8	...	...	...	...	...	40	410	55	29	4.8	414
10	*Phragmites*	12.5	6.7	...	5:1	130	3	...	...	...	...	...	...	40	440	70	35	6.2	510
11	Rice straw[a]	8.0	4.0	...	7:1	170	2	43.5	19.3	21.5	5.7	...	14.8	...	500	66	31	5.8	40
									Neutral Sulfite Cook										
12	*Phragmites*	6.0	...	12.0	5:1	150	3	52.7	1.8	18.1	5.7	73.7	15.2	85	460	66	30	6.6	227

[a] The rice straw data were supplied by the Northern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, Peoria, Ill. The data were acquired in 1953 when the author worked at the Northern Laboratory as a trainee under the auspices of the Technical Collaboration Branch, Foreign Agricultural Service, U. S. Department of Agriculture. Interpretations are those of the author.

15 ft. long, and 0.16 to 0.72 in. diam. A representative sample of the reed was reduced to meal by using a Wiley mill, and analyzed. The approximate chemical analysis of the reed, which includes ash, total extractives, α-cellulose (*7*), and pentosans (*8*) is given in Table II. In the α-cellulose determination, the holocellulose was treated with 18.6% NaOH and subsequently weighed as α-cellulose. The pulp fibers were 0.2 to 2.7 mm. long and 0.007 to 0.032 mm. in width.

PULP PREPARATION AND TESTING

The reeds contained a small percentage of dry flowers and had retained their sheaths. The reeds were cut to a length of 1 to 2 in. and cooked by the soda, kraft and neutral sulfite procedures. The digestion was carried out in a gas-heated, stationary vertical autoclave, at the specified conditions given in Table III; approximately 30 min. were required to attain the cooking temperature. Following digestion, the pulps were washed free of chemicals, disintegrated in a British disintegrator, washed,* and the yields determined. The pulps thus obtained were analyzed for ash, α-cellulose, Klason lignin, pentosan (*9*) and permanganate number (*10*).

The rice straw cooks† were carried out in a steam-jacketed tumbling autoclave at the conditions given in Table III. The yields in this case are based on the screened pulp. The screening of the straw pulp was done in a 4-cut laboratory flat screen with 0.008-in. openings, and the screened pulp passed over a 100-mesh wire to eliminate the fines.

Testing

Beating and strength evaluation of the pulps were carried out in accordance with the standard TAPPI methods. The results are shown in Tables III and IV.

Reed-Kraft Wood Pulp Blends

The different reed pulps were beaten to the stated freeness (Table IV). The desired amount of the beaten kraft wood pulp (an imported kraft softwood pulp) was added, and the blend mixed in the British disintegrator for 10 min., followed by evaluating the papers for strength properties. The results are shown in Table IV.

Mill Run Trials

The reeds were cut to a length of about 1 to 2 in. by a rotating knife cutter, followed by digestion in a rotating spherical digester at the National Paper Co., Alexandria. The disintegrated and washed reed pulp was then tested by passage through the plant's continuous beater. The results are shown in Table V. Plant-run trials were then carried out on the refined and beaten reed-kraft wood pulp blends. The performance on the fourdrinier paper machine was normal, and the results are given in Table V.

RESULTS AND DISCUSSION

The chemical analysis of the analyzed Egyptian *Phragmites communis* (L.) is fairly similar to the reported analysis of *Phragmites* from different geo-

* The washing was done on a screen with 1 mm. perforations.
† See footnote in Table III.

Table IV. Strength Characteristics of Reed Kraft Wood Pulp Blends

Expt. no.	Reed pulp[a] Chemical NaOH, %	Chemical Na_2S, %	Chemical Na_2SO_3, %	°S.-R. freeness, ml.[b]	Furnish Reed pulp, %	Furnish Kraft pulp, %	Physical properties of pulps Basis weight g.s.m.	Burst p.s.i.	Tensile, kg./15 mm. width	Double fold, Schopper
				Reed (Soda) Kraft Wood Pulp Blends						
1	...	...	...	...	...	100	58	69	8.0	3104
2	16.2	...	...	510	100	...	69	29	5.5	166
					50	50	57	40	7.0	982
3	17.7	...	...	420	100	...	68	37	7.3	464
					50	50	52	38	6.4	4115
4	19.2	...	...	430	100	...	68	39	7.1	607
					50	50	61	49	6.6	6220
5	20.7	...	...	490	100	...	61	34	6.9	462
					50	50	57	46	6.8	2666
6	21.9	...	...	520	100	...	70	43	7.2	614
					50	50	61	44	7.4	2786
				Reed (Kraft) Kraft Wood Pulp Blends						
7	12.1	4.1	...	455	100	...	70	40	7.1	447
					50	50	62	44	8.2	5047
8	12.5	6.7	...	410	100	...	55	29	4.8	414
					50	50	72	53	8.8	3074
				Reed (Neutral Sulfite) Kraft Wood Pulp Blend						
9	6.0	...	12.0	460	100	...	66	30	6.6	227
					50	50	63	50	6.6	1545

[a] Details of pulp preparation in Table III.
[b] The values for the °S.-R. are those for the beaten pulps before blending.
[c] An imported kraft wood pulp beaten to °S.-R. of 490 ml. before blending.

graphic areas (*1–6*). Compared with rice straw, the reed had more α-cellulose, lignin, and much less ash. The high lignin content of the reeds indicates that it will require more chemicals for pulping. This is borne out by test, and is shown in Table III. An inspection of these data, shows that the reeds are more difficult to pulp, and require about 17% chemicals at 150°C. for 3 hr. to give a satisfactory pulp, while rice straw is easier to pulp and requires about 12% NaOH at 170°C. for 2 hr. The data (Table III) show also that the reeds could be pulped by the soda, kraft, and neutral sulfite processes. The pulp yield of the different cooks is rather high, ranging between 43.5 to 52.7%, and this is attributed to the high α-cellulose content of the reeds (44.75%).

Soda pulping of the reeds show that increasing the NaOH percentage from 16.2 to 21.9% at a fixed liquid: solid ratio at 150°C. for 3 hr. resulted, as expected, in a gradual lowering of the pentosans, lignin and permanganate number with a progressive increase in the α-cellulose content. The minimum lignin content (2.7%) was, however, obtained by pulping with 20.7% NaOH. Burst and tensile characteristics of the soda pulps were nearly the same for concentrations of NaOH ranging from 17.7 to 21.9%. In comparison with soda pulping of rice straw, the soda reed pulps were superior as far as tensile and fold properties.

The kraft pulping of the reeds was found to be very effective, and the optimum cook no. 8 (14.2 NaOH and 3.5% Na_2S), gave the best pulp in strength properties (burst, tensile, and fold) in comparison with the other cooks of Table III. Again, kraft pulping of the reeds gave much better pulps compared with the kraft rice straw pulp.

The neutral sulfite pulp gave the highest yield of all the pulps (52.7%) and the lowest permanganate number, but had lower strength properties compared with the other pulps. Based on overall data, the results of Table III indicate the suitability of using the reeds as a pulp source, with the optimum results obtained with a kraft cook using 14.2% NaOH and 3.5% Na_2S, followed by the alkali cooks using 17.7 to 20.7% NaOH. Both types of reed pulps are superior to soda and kraft rice straw pulps.

Strength characteristics of reed-kraft wood pulp blends (50:50) were evaluated as in Table IV. The different reed pulps were beaten separately to the stated freeness (Table IV), the desired amount of the beaten kraft wood pulp added, followed by evaluating the papers for strength properties. The results obtained are rather interesting because in the majority of cases, the folding endurance of the blends are superior to those of either component alone. There is also an increase in the tensile strength in the kraft reed pulp blends (experiment nos. 7 and 8, Table IV), and a slight lowering in the burst strength in all the blends in comparison with the arithmetical mean of the components.

Following this study, plant-run trials were carried out on the uncleaned and cut reeds. The digestion was carried out satisfactorily in the rotary digesters of the National Paper Co., Alexandria, and the ease of

Table V. Plant-Run Trials on Reed and Reed Kraft Wood Pulp Blend

Expt. no.	Furnish Reed pulp, %	Furnish Kraft pulp, %	Processing equipment	Physical properties of pulp Burst, lb.	Tensile M. D.	Tensile C. D.	Double fold, Schopper M. D.	Double fold, Schopper C. D.
1	100	...	Continuous beater—200[a] amp.	21	4.0		218[b]	
2	100	...	Continuous beater—230[a] amp.	22	4.7		115[b]	
3	...	100	Continuous beater—240[a] amp.	22	4.1		475[b]	
4	20	80	Paper mill's refining equipment, and fourdrinier machine	25	6.1	2.8	1067	140

[a] The °S.-R. freeness at 200 amp. was acceptable, but at 230 amp. the °S.-R. was low.
[b] Laboratory sheet values. All strength values are for 60 g. papers.

charging the digesters in comparison with the rice straw allowed the charge to be increased. It was observed, also, that the reed pulp needed more effective beating to develop its strength properties than is the case with rice straw pulps. Running the reed pulp, in a single pass, in the plant's continuous beater was effective in developing the strength properties of the pulp, as seen by a comparison of the results in Tables V (experiments nos. 1 and 2), and III. Of interest in this respect is that running the kraft wood pulp in a single pass in the continuous beater gave nearly the same strength properties as that of the reed pulp (Table V). It should be stated, however, that following the continuous beater run, the freeness of the reed pulp was rather low, while the high freeness of the kraft wood pulp allowed for its further strength development in the Hollander beater. Plant-run trials were carried out on the refined and beaten reed-kraft wood pulp blends. The performance on the fourdrinier paper machine was normal, and the results are shown in Table V. The reed is now supplementing the rice straw as a pulp source in Egypt.

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Predicting Paper Printing Quality by the "Battery of Tests" Method

ALEX. GLASSMAN

A method for evaluation and prediction of paper properties important for 4-color rotogravure print quality has been determined. This method has been found to apply over a wide range of paper grades covering (1) coated and uncoated as well as (2) wide variations in pulp furnish (groundwood and groundwood-free) (3) and changes in finish varying from supered to unsupered (4) with some papers carbonate filled, others clay filled. A number of excellent methods are in use that appear to correlate well for a given grade of paper, such as for groundwood (*1*), machine-coated (*2*), or paperboard (*3*). These methods appear to work well for a given group of papers made on similar equipment from similar furnishes. Experience has shown that no known method could fully explain in numerical fashion why many uncoated papers print smoothly whereas at similar test values coated papers print with such extreme graininess as to be commercially of very poor quality. This paper describes how through the cooperation of a group,* representing five paper companies, an inkmaker and a printer, a precise press trial was made, which together with laboratory work has led to separation of the effects of ink, press, and paper. With respect to paper it was found that no single test could explain the observed effects, but that with a battery of as few as four tests an extremely high correlation was obtained. A coefficient of multiple correlation 0.892 was typically obtained through the use of a selected battery of tests, although in many instances the individual tests had very much poorer correlation coefficients, in some cases far below 0.50. Using an IBM 610 Computer, typical equations were determined, relating laboratory tests with commercial four-color print quality.

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* Participating companies: Ink and test facilities: InTag division of Interchemical Corp.; several papers supplied by each: Mead Corp., Consolidated Water Power and Paper Co., St. Regis Paper Co., Provincial Paper (Canada), Kimberly-Clark Corp. Printer: R. R. Donnelley & Sons Co. In addition some European paper was included in this test, courtesy of R. R. Donnelley & Sons.

THE quality obtained in four-color rotogravure printing varies over a very wide range on papers that appear quite similar in nature, as for example on machine-coated papers. Quite often large quality differences occur on similar presses using normal rotogravure inks. Frequently, press operators ascribe their difficulties to paper and/or ink. Ink and paper suppliers show that according to their tests they supplied standard materials.

In order to obtain some basic understanding of the principal factors involved in gravure quality, it was decided to test under highly controlled press conditions a series of inks and papers over a wide range of printing pressures.

All tests were made at 1000 ± 5 f.p.m. on a 20-in. four-color Champlain press. The printing cylinder, impression cylinder hardness, and air drying temperatures were carefully selected to represent best commercial practices. The details of each of these are appended to this report.

Three inks were used in this trial that represent the range of the best inks normally used in four-color printing for magazine work. Prior to the trial, a series of preliminary tests were conducted to select the optimum viscosity for each ink.

The printing pressures selected were 60 and 90 lb. per lineal in., and were intended to cover commercial practice. However, after the first complete ink trial it was decided to add a third pressure 150 lb. per lineal in. for inks nos. 2 and 3.

A total of 14 papers were supplied for this trial. Each of the five suppliers agreed to select what they considered a "good" and a "poor" roll, but one mill supplied more than two rolls and they did not feel cer-

Table I. Description of Paper

Code no.	*Description*
2	Coated high finish
3	Coated low finish
3A	Same as no. 3 but different date of manufacture
4	Coated high finish
4A	Same as no. 4 but different date of manufacture
5	Uncoated regular finish
6	Coated book—low finish
7	Coated book—high finish
8	Carbonate super
9	Carbonate super—"higher grade"
10	Groundwood super—low finish
11	Groundwood super—high finish
12	Groundwood coated
13	Uncoated groundwood
14	Duplicate of no. 8
15	Duplicate of no. 5

tain that the differences in their first log was large. This same supplier also supplied a best and worst in coated stocks of radically different coating composition. Table I lists the description of each of the 14 papers as well as the two replicate samples used throughout the evaluation procedures.

Included in the 14 papers was a European groundwood paper upon which very high quality printing is obtained.

Most of the tests were printed wire side only. There was a total of 126 combinations of paper-ink-press. Of these, 105 were made on the wire side as this is the major area of difficulty. However, sufficient felt sides were included so that the range of paper properties could be evaluated.

The method of evaluating four-color rotogravure print quality selected was the jury panel. Standardized instructions, attached in the appendix to this report, were given to each quality "judge" together with formal "data sheets." Each of the participating companies was invited to rank each of the 126 coded prints from best (rank 1) to worst (rank 126) by not less than two of their most qualified observers. At R. R. Donnelley the people who judged these prints included the top quality man in production, research, and operating. Similarly in the four paper companies who participated in the evaluation top individuals responsible for technical service in gravure plants, or in research were used.

Agreement between the 14 judges was amazingly good. Samples 8 and 14 as well as 5 and 15 are duplicates that demonstrate the high degree of reliability of the judges' rankings (Table II).

Table III lists the average jury panel ranking for the 105 combinations of ink-paper-pressure used for wire side printing.

From Table IIIa and IIIb it is clearly evident that ink B is far superior in this test to the other two inks, that "AC" is next, and "AB" is the poorest. It is clear therefore that ink represents a very large and

Table II. Average Jury Rank

Ink	*Pressure, p.l.i.*	*Paper no. 8*	*Duplicate paper no. 14*
B	150	13	14
	90	31	42
	60	66	69
AB	150	62	70
	90	84	89
	60	113	112
AC	90	62	66
	60	90	93

Table III. Average Jury Panel Ranking

Wire Side Only

1.	B-11-150	36.	AC-15- 90	71.	AB- 8- 90
2.	B- 5-150	37.	AC-11- 60	72.	AC- 7- 60
3.	B-10-150	38.	B- 9-150	73.	AB-14- 90
4.	B-15-150	39.	B- 3-150	74.	AC- 6- 90
5.	B- 7-150	40.	B- 7- 60	75.	B- 3- 90
6.	B- 2-150	41.	AC- 9- 90	76.	AC- 8- 60
7.	AB-11-150	42.	B- 6- 60	77.	AB- 4-150
8.	B- 8-150	43.	AB-12-150	78.	AC- 2- 60
9.	AC-13-150	44.	AC-12- 60	79.	AC-14- 60
10.	B-14-150	45.	B- 9- 90	80.	AB- 3-150
11.	B- 6-150	46.	B- 5- 60	81.	AC- 9- 60
12.	AB-10-150	47.	AB-15- 90	82.	AB- 9- 90
13.	B-11- 90	48.	B-11- 60	83.	AB-12- 90
14.	AC-11- 90	49.	B-15- 60	84.	AB- 2- 60
15.	AB- 5-150	50.	AB- 8-150	85.	AB- 5- 60
16.	B-15- 90	51.	AC- 8- 90	86.	AB- 6- 60
17.	AB-15-150	52.	AC- 5- 60	87.	B- 9- 60
18.	B- 7- 90	53.	AB- 5- 90	88.	B-12- 60
19.	AB-10- 90	54.	AB- 7- 90	89.	AB-15- 60
20.	B- 5- 90	55.	AC- 7- 90	90.	B- 4- 60
21.	B-12-150	56.	AB- 9-150	91.	AC- 3- 90
22.	AB- 7-150	57.	B- 8- 60	92.	AC- 6- 60
23.	B- 8- 90	58.	AC-14- 90	93.	AC- 4- 90
24.	B-10- 90	59.	B-14- 60	94.	B- 3- 60
25.	B- 2- 90	60.	AB-14-150	95.	AB-14- 60
26.	B- 6- 90	61.	AC- 2- 90	96.	AB- 7- 60
27.	AC-10- 90	62.	B- 2- 60	97.	AB- 8- 60
28.	AB-11- 90	63.	AB-11- 60	98.	AB- 9- 60
29.	B- 4-150	64.	AC-10- 60	99.	AB- 3- 90
30.	AB- 2-150	65.	B-10- 60	100.	AB- 4- 90
31.	AB-10- 60	66.	AB- 2- 90	101.	AC- 4- 60
32.	B-14- 90	67.	B-12- 90	102.	AC- 3- 60
33.	AC- 5- 90	68.	AB- 6- 90	103.	AB-12- 60
34.	AC-13- 90	69.	AC-15- 60	104.	AB- 4- 60
35.	AB- 6-150	70.	B- 4- 90	105.	AB- 3- 60

Code: *Nos. 1 to 105:* represent av. Jury Rank. No. 1 is best printed. No. 105 is worst printed.
B, AB, AC: represent Ink.
Next digit: 2 to 15 represents Paper.
The last digit: 60, 90, or 150 represents Pressure applied at the press.

important area of variation of rotogravure quality at any given paper-pressure combination.

Similarly the effect of pressure is plainly evident at any ink-paper combination and that it is a very important determinant of roto quality.

As shown by Table IV, for example, paper no. 8 is improved in rating from 113th out of 126 (practically the worst) to 62nd by change of pressure from 60 to 150 lb. per lineal in. with ink "AB" and from 66th to 13th (practically top quality gravure) with ink "B."

Paper no. 8 is thus changed from almost the "worst" paper to almost "best" by the combination of ink and pressure.

Table V emphasizes the paper factor. In this recap of the jury panel rankings, it can readily be seen that at one and the same ink and pressure, one paper of a given grade, produced a top quality job, represented by

Table IIIa. Average Jury Panel Rankings

	Ink B	*Ink AC*	*Ink AB*
150 p.l.i.	13	..	39
90 p.l.i.	35	51	65
60 p.l.i.	64	73	87

Table IIIb.

Best Ink At Any {Given Pressure / Given Paper}	Combination
96.0% of the time	Ink B
2.7% of the time	Ink AB
1.3% of the time	Ink AC

Table IV. Average Jury Rank—Paper No. 8

Ink	60 p.l.i.	90 p.l.i.	150 p.l.i.
B	66	31	13
AC	90	62	..
AB	113	84	62

the paper in the 1st column, whereas a paper of the same grade and finish (see column 3), ranked 40th! Thus we see how very important is the paper factor.

It was at this point that we said "Eureka!" We will test each of these 14 papers by all known tests, and even include some we formulated specially for this trial. Surely one of these tests will correlate with the observed results and be useful as a predicator. Tests made included drawdowns (*4*), proof presses, Proficorder, electron microscope as well as many others, such as wipes (*4*). To our dismay almost all of these tests only strikingly separate the papers into two categories—coated and uncoated, and only a precision roto proof press test was able to predict with reasonable reliability the quality differences observed by the jury panel. Figure 3 is a plot of smoothness versus jury panel results and shows clearly the futility of attempting to predict printed four-color smoothness from air leak smoothness tests. Figure 1 shows a similar plot for gloss; Fig. 2 show I.G.T. print tests at 60 kg. These graphs merely illustrate some of the test results.

Table VI lists the average jury panel ranks and average bench test results for coated and uncoated papers, printed at 60 and 90 lb. per lineal in. with ink B. The results shown are typical of other inks and pressures. As seen by the panel ranks, the uncoated papers printed more smoothly than the coated papers at both printing pressures. However, both an optical smoothness test (gloss) and an air leak smoothness test (Bekk) indicated that the coated papers had much greater surface smoothness than the uncoated papers. We would therefore expect them to print better. The letterpress proof press test results also indicate very strongly that the coated papers should print better than the uncoated papers. In this test the lower numbers represent better test prints. The only test which agreed with the jury panel judgment of printed result was rotogravure proof press test. Low numbers for this test indicate better test prints.

At this point a thorough analysis of the relationships between bench test results and jury panel ranks was made, using statistical methods. The first step was to examine the correlation between each bench test and the jury panel judgments. The statistical parameter used was the correlation coefficient. This value will vary from −1.000 to +1.000, with 0 representing no correlation and either extreme representing perfect correlation. For the number of papers tested the correlation coefficient must be 0.700 or greater to be statistically significant, i.e., not likely to occur by chance. Table VII lists the correlation coefficients determined for papers printed with ink B at 60 p.l.i. These results are typical of other inks and pressures. For the coated papers, only the two proof press tests correlate significantly with the jury panel results. The only test found to correlate significantly with the jury panel ranks when both coated and uncoated papers were combined was the rotogravure proof press test.

Past experience in predicting paper printability from bench tests has indicated that in general no single test will do as good a job of prediction as a combination or battery of appropriate tests. Therefore, the trial data were looked at with this in mind. As a measure of the efficiency of a battery of tests multiple correlation coefficients were calculated. These coefficients express the degree of correlation between the jury panel ranks and the combined effect of several bench tests. As for the simple correlation coefficient, the correlation is perfect when the multiple correlation coefficient is 1.00.

Fortunately an IBM 610 computer was available and the calculations of multiple correlation coefficients were easily made. This work involves the solution of a number of simultaneous equations and can be very tedious if carried out by conventional hand methods. It is greatly simplified by use of the Abbreviated Doolittle Method, which may be found on page 302 of

Table V. Recap Jury Panel Averages—Each Paper-Each Pressure-Each Ink

Ink	Pressure	Coated high finish	Coated low finish	Coated high finish	Uncoated regular finish	Coated book low finish	Coated book high finish	Carbonate super	Carbonate super	Ground wood low finish	Ground wood high finish	Ground wood coated	Carbonate super	Uncoated regular finish
		2	3	4	5	6	7	8	9	10	11	12	14	15
B	150	12	56	40	7	15	9	13	52	8	3	30	14	9
	90	32	90	77	30	37	28	31	59	32	17	75	42	25
	60	72	111	106	61	57	56	66	100	73	62	100	69	62
AB	150	40	94	92	24	46	30	62	64	16	12	58	70	26
	90	73	115	115	63	75	63	84	95	28	38	95	89	61
	60	99	125	125	99	99	113	113	114	40	72	122	112	104
AC	90	70	106	109	43	89	63	62	56	37	23	45	66	47
	60	93	121	120	62	108	88	90	94	72	48	58	93	76
	150	..	..	..	..	..	..	..	..	..	..	13	..	..

Table VI. Average Results—Ink B

	Jury panel rank 60 p.l.i.	Jury panel rank 90 p.l.i.	Gloss	Roto proof press test	L.P. proof press test	Bekk smoothness
Coated papers	88	60	45	5.3	3.9	840
Uncoated papers	74	34	21	3.6	6.9	283

Table VII. Correlation Coefficients—Ink B, 60 p.l.i.

	Coated papers	Uncoated papers	All papers
Jury versus gloss	0.170	0.384	0.224
Jury versus roto proof press	0.877	0.325	0.820
Jury versus L.P. proof press	0.784	0.555	0.100
Jury versus Bekk smoothness	−0.547	−0.624	−0.009
Multiple correlation	0.959	Insufficient sample size	0.892

"Statistical Analysis in Chemistry and the Chemical Industry" by Bennett and Franklin.

Table VII lists the multiple correlation coefficients for papers printed at 60 lb. per lineal in. with Ink B. These are typical of coefficients obtained for other inks and pressures. The improvement in degree of predictability using a battery of tests is greater than the difference in coefficients may indicate. This is because the amount of variation in jury panel rank, which is explained by the bench test or tests, is a function of the square of the correlation coefficient. For example, the correlation coefficient for all papers for the jury rank versus roto proof press is 0.820. The square of this value, expressed as a percentage, indicates that 67% of the variation in printability is explained by the roto proof press results. The multiple coefficient for all papers is 0.892, indicating that 80% of the variation in printability is explained by the battery of tests considered.

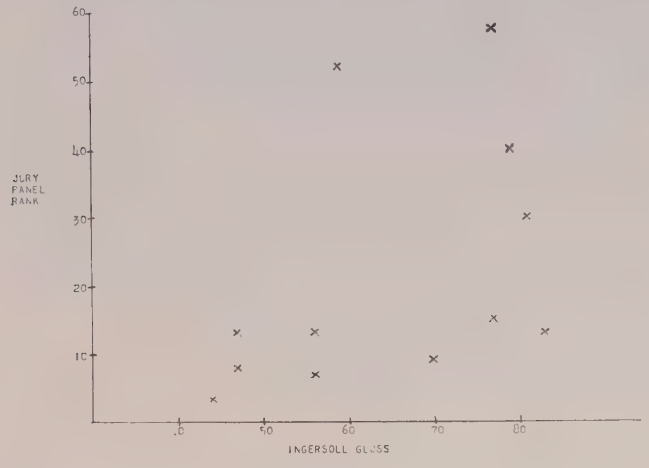

Fig. 1

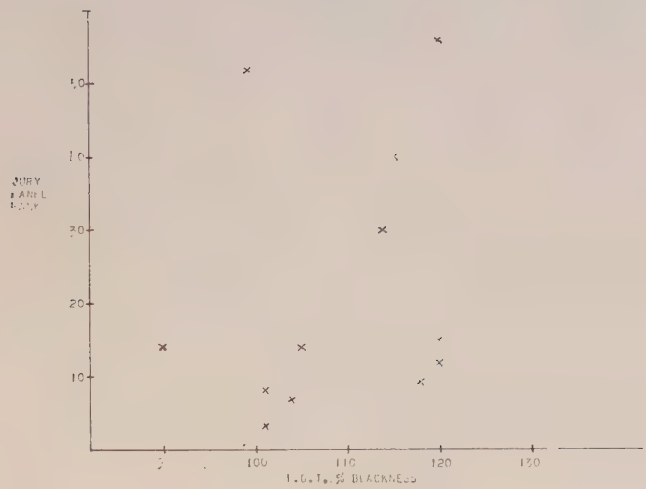

Fig. 2

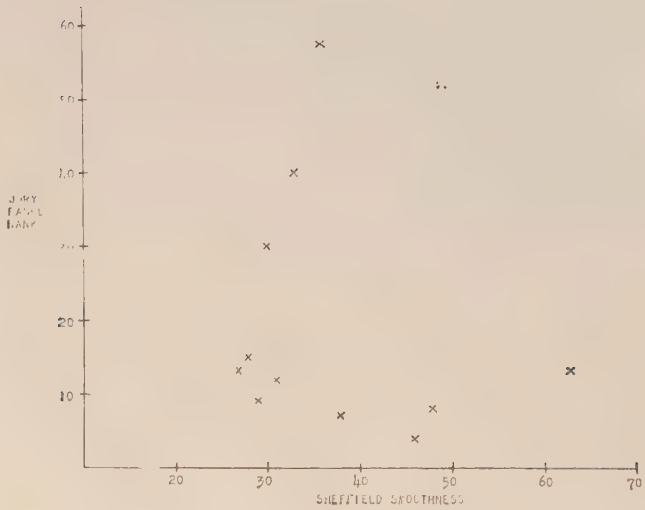

Fig. 3

It is possible to calculate an equation which can be used to predict the jury panel rank. For the coated papers printed at 60 lb. per lineal in. with ink B:

$$Y = 18.57 - 0.10X_1 + 7.98X_2 + 10.13X_3 - 0.01X_4$$

where:

Y = predicted jury rank
X_1 = gloss
X_2 = roto proof press test
X_3 = letterpress proof press test
X_4 = Bekk smoothness

Figure 4 illustrates the relationship between the jury panel ranks predicted by this equation and the actual jury panel ranks obtained.

The corresponding equation for both coated and uncoated papers together is:

$$Y = 9.99 - 0.35X_1 + 12.29X_2 + 4.21X_3 + 0.01X_4$$

Figure 5 illustrates the relationship between the jury panel ranks predicted by this equation and the actual jury panel ranks obtained.

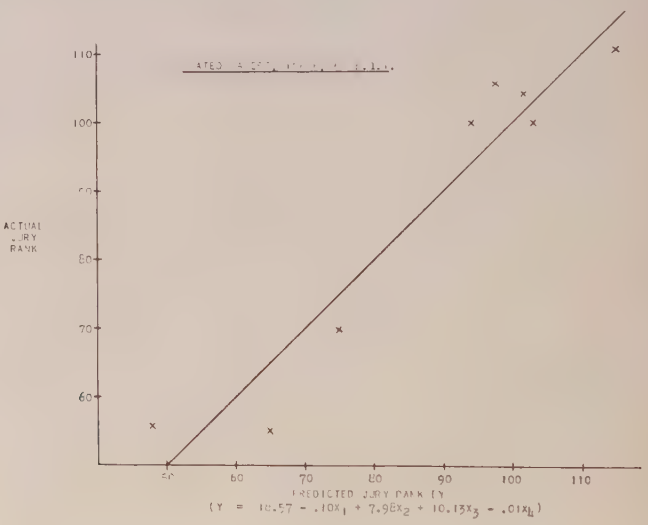

Fig. 4

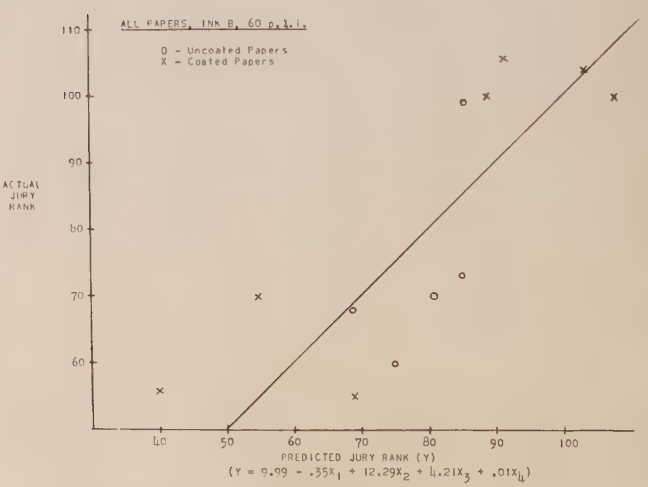

Fig. 5

In conclusion, these experiments have been successful in isolating the importance of each of the three factors—ink–pressure–paper, and how each in itself is sufficient to "make" or "break" the quality of a four-color gravure job.

Papermakers, inkmakers, and press operators now each have a quantitative method of determining with assurance the degree of contribution to quality they can make to the total printing job. They also can measure the limitations of quality within the particular paper–press–ink system they operate within.

APPENDIX

1. Press Conditions

   Impression roller hardness: Durometer of rolls used 83

Nip Width at Pressures Applied

Pressure *p.l.i*	Nip width in 1/32 in.
60	4.5
90	6.0
150	10.0

Oven temperature: 140°F.

Cylinder data: Gresham Etch
Screen ruling, 150

2. Evaluation Form

Cooperative Study of Four-Color Rotogravure Printing

Ink	*Paper*	*Printing*
In tag division	Five paper companies	R. R. Donnelley

The object of this study is to determine ink, paper, and impression conditions conductive to highest quality with regard to: (1.) smoothness of tones, and (2.) gloss of inked area.

Please let me know if you wish to participate in a co-operative evaluation for these two properties. Those who participate will receive a coded list of ratings made by all companies. At least two individuals should perform the ratings from each company.

These are two attributes to be rated and these should be made separately. They are: 1. smoothness, and 2. gloss of inked area.

Do not penalize signatures for differences in color, for scratches, or for obvious errors in inking.

Please arrange the entire set of signatures in order of smoothness. No. 1 is best. No. 126 is worst.

Use only the picture identified with a cross hairline (not the "T" hairline) in making the evaluation, making sure that the samples are well shuffled before starting.

1. Rating for Smoothness

   Please rate with particular reference to smoothness of printing.

   Penalize heavily graininess such as occurs in lower left hand corner of picture.

   Penalize roughness and wiremark.

   Penalize lack of contrast.

   Shuffle the entire set of signatures so that they are not in any special sequence.

2. Rating for Gloss of Inked Area

   No. 1 is best.

   No. 126 is worst.

   Please rate with reference to gloss of inked areas such as: a. Black solid area at bottom (center) of picture; b. Punch bowl.

It is suggested because of the large number of samples that:

1. A large table with reasonable illumination be used.
2. The samples be sorted first in a preliminary way into four or five major groups. Then, individual comparisons should be made within and between groups until the entire 126 are rated.

It is preferable that each person rating these signatures use a *different* set of signatures. It is to be expected that several instances will occur where the differences will be small. However, even in these instances it is best to arrange the samples in order.

The entire rating must be done at one time for one attribute.

We invite your participation in this study. Please send results to: Alex. Glassman, Quality Inspection Department R. R. Donnelley & Sons Co., 350 East 22 St., Chicago 16, Ill., if you wish to participate.

This report deals only with the results of the ratings for smoothness of tones.

3. Note on Inks

   Inks used were three publication inks in use in 1957–58. They are not intended to cover the gamut of inks, but rather to find out if differences due to ink could be isolated. It is believed that very large differences in present quality exist within each of the types of ink used in this trial.

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Acknowledgments: John Hoffman, manager of Quality and Measurements System, Kimberly-Clark, is responsible for a major portion of the statistical analysis. He personally led in many of the efforts to arrive at an analysis of the original test data, and only by his persistence were the final results obtained that are reported in this paper. Gerald L. Swope, paper quality control supervisor, R. R. Donnelley, is responsible for obtaining and analyzing the quality rankings of the four-color gravure prints. Much of the early laboratory work was conducted under the supervision of Mr. Swope. Harry H. Hull assisted Mr. Swope in setting up the ranking system and standardized instructions used. Hugh Dunn, technical director in 1958 of the Printing Ink Division, Interchemical Corp., Lodi, N. J., was responsible for the direction of all the work preliminary to the running of the press test to insure standardized conditions. During the week-long test he personally supervised a group that maintained within the agreed limits all of the controlled factors (ink viscosity, drying temperature, speed, pressure, register, color). Thanks is due to Fred A. Weymouth, vice president, Interchemical Corp.; and J. A. Quigley, president of their InTaglio division, for their assistance and collaboration. H. B. Tellschow, vice president, R. R. Donnelley, envisioned the need for greater understanding of the fundamental factors involved in four-color gravure printing and helped initiate the program.

Investigations of the Mannans and Xylans in Softwood. II

ALFRED J. MORAK and KYLE WARD, JR.

An investigation of the sequential use of aqueous potassium hydroxide, alkaline potassium borate, and sodium hydroxide extractions of holocelluloses from sprucewood and pulp has shown that most of the xylans are removed as a heterogeneous mixture, containing large amounts of glucose and mannose. The second stage (borate) removes a glucomannan (about 75% mannan) in a pure state (about 1% xylan) even without fractionation. The product from the final extraction is also very low in xylan, but there is much more glucose than mannose in the hydrolyzate. The x-ray diffraction patterns and molecular size of the unfractionated hemicellulose mixtures have been determined and are discussed.

In a previous investigation (*1*, *2*), alkaline extraction of holocelluloses from sprucewood, sulfite, and kraft pulps by treatments with potassium hydroxide, followed by potassium metaborate, were found suitable for the preparation of a hemicellulose of particularly high xylan content and another of a particularly high glucomannan content. Yet, in a quantitative sense, this combination of extractions proved to be rather inefficient for the removal of mannan. It appeared of interest to investigate the possibility that a glucose-rich glucomannan had been left unextracted in the cellulose residue. The isolation of this expected hemicellulose by means of additional sodium hydroxide treatments and the characterization of the hemicellulose fractions was the purpose of this investigation.

INTRODUCTION

The results of the earlier investigations proved that the combination of sodium hydroxide-potassium hydroxide treatments was the most efficient procedure for removing nonglucose sugars, whereas the potassium hydroxide-potassium metaborate treatments proved least efficient for the quantitative removal of mannans (*2*). It appeared, therefore, that a glucomannan might still remain in the cellulosic residue from the potassium hydroxide-potassium metaborate extraction procedure. Probably this might be isolated by means of added sodium hydroxide treatments. The potassium hydroxide treatments produced a high-xylan-content hemicellulose, while the potassium metaborate treatments yielded a practically xylan-free glucomannan. It should also be possible to extract selectively another essentially xylan-free, mannose-containing polysaccharide by a third sodium hydroxide extraction. These three hemicelluloses should serve as suitable starting materials for further structural investigations.

This present work deals with the alkaline extraction of chlorite holocellulose from sprucewood, sulfite, and kraft pulps by means of sequential potassium hydroxide, potassium metaborate, and sodium hydroxide extractions. As the same raw materials used in the earlier work were available the results of this investigation extends those reported previously (*1*, *2*).

The scope of this investigation comprised the preparation of chlorite holocelluloses from solvent- and water-extracted raw materials, their alkaline extraction with potassium hydroxide treatments of various concentrations, with potassium metaborate treatments, followed finally with sodium hydroxide treatments of various concentrations, and the quantitative recovery of the respective hemicelluloses. The yield of the latter, as well as their sugar ratios, their viscosities and limiting viscosity numbers, and finally the yields of cellulosic residues were determined. Optical rotations were measured on the hemicelluloses, and x-ray data collected on all samples of extracted hemicelluloses, the purified raw materials, the chlorite holocelluloses and the cellulosic residues after the potassium hydroxide, and the sodium hydroxide treatments. Solutions of two hemicelluloses were prepared for molecular weight determinations by means of light-scattering and ultracentrifugation methods. Finally, electronmicrographs were prepared of the high-xylan hemicellulose extracted with potassium hydroxide.

EXPERIMENTAL

Raw Materials

The materials used in this investigation are again designated S_1, S_2, S_3, and S_5 and consist of the following:

- S_1 Sprucewood chips (*Picea excelsa*)
- S_2 Unbleached sulfite pulp (from S_1)—Cook I
- S_3 Unbleached sulfite pulp (from S_1)—Cooks III and IV
- S_5 Unbleached kraft pulp from a second sample of spruce chips (S_4) which had been previously shown to be similar to S_1 (*1*, *2*).

The air-dried samples were ground in the Wiley mill (mesh no. 4) and the fraction passing through no. 40-mesh and remaining on no. 60-mesh screens was taken for purification, by first extracting for 6 hr. with an ethanol:benzene (1:2) mixture, followed by a 6-hr. extraction with 95% ethanol in Soxhlet extractors, and finally by a 5-hr. water extraction at a consistency of 2% at 30°C. with frequent agitation. Here the distilled water used had a pH of 6.2, the aqueous extract of S_1, S_2, S_3, and S_5, a pH of 5.8, 6.3, 6.3, and 8.5, respectively. An amount of distilled water equal to that used for the extractions was employed for washing of the cellulosic materials on the sintered-glass Buchner-type funnels. There was no pH control during the extraction. The air-dried purified materials were chlorited according to the method of Wise, *et al.* (*3*). The two sulfite pulps S_2 and S_3 were chlorited for 3 hr., the kraft pulp for 4 hr., and the sprucewood sample S_1 for 5 hr. The holocellulose of S_1 was slightly yellowish with a Klason lignin content of 1.13% and a cuprammonium viscosity of 17.5 cp.

Alfred J. Morak, Research Aide, and Kyle Ward, Jr., Chief, Cellulose Group, The Institute of Paper Chemistry, Appleton, Wis.

Extraction of the Chlorite Holocelluloses

All alkaline extractions were carried out on 40-g. samples under nitrogen in sealed containers at a controlled temperature of 23 ± 0.5°C. and at 6 r.p.m. of the rotator. Each holocellulose was treated at a 2% consistency once for 24 hr. with 3.4 *N* potassium hydroxide (16.7% w/w), followed by two 24-hr. extractions with 1.95 *N* potassium hydroxide (10.0% w/w), then at a 5% consistency twice for 2 hr., and subsequently for 22 hr. with alkaline potassium metaborate (223 g. potassium hydroxide and 120 g. boric acid per liter), followed finally at a 1% consistency by one 24-hr. extraction with 3.4 *N* sodium hydroxide (12.0% w/w) and two 24-hr. extractions with 1.9 *N* sodium hydroxide (7.1% w/w). In each of these treatments the cellulosic residues were always filtered on a Buchner-type fritted-glass funnel after the first and second extraction to remove the alkaline hemicellulose extracts. The residues then were immediately subjected to the third extraction. After each third extraction the filtered cellulose residues were washed with 5% potassium hydroxide in the first two treatments and with a 3% sodium hydroxide solution in the third treatment, washed with water, neutralized, then washed free from acid, and air-dried. Small samples of the cellulosic residues were removed for moisture determinations by drying them *in vacuo* at 58°C. overnight. The filtrates containing the hemicelluloses were immediately acidified with glacial acetic acid, cooled, and 95% ethanol was added to attain a final ethanol concentration of 70%. After standing for one day (in two cases three days were necessary for clearing) the supernatant liquors, containing the alcohol-soluble hemicelluloses, were removed and the alcohol-insoluble precipitates were washed with 80, 85, 90, and 95% ethanol, then solvent exchanged with hot absolute ethanol and methanol, and finally with ethyl ether. All hemicelluloses were dried from ether *in vacuo* at 45°C. The supernatant liquors after the precipitation of the hemicelluloses after the first and second potassium hydroxide extraction treatments were freed from ethanol by distillation and the remaining aqueous solutions were slightly concentrated. These concentrates were dialyzed against distilled water, resulting in a nearly complete removal of potassium acetate. Then they were again concentrated, dialyzed, and passed through an ion-exchange column of IR 120 (H) in order to remove any residual cationic materials. The resulting solutions of alcohol-soluble hemicelluloses were almost ash-free and were concentrated in a rotary evaporator *in vacuo* at 40°C. A sizable portion of lower molecular weight material passed through the dialysis membrane and the recovery of this material was accomplished by means of a large IR 120 (H) column. The resulting liquor was evaporated in a large flash evaporator, the concentrate obtained was passed through a small IR 120 (H) column, and the practically ash-free solution was evaporated to dryness *in vacuo* at 45°C. The quantities of alcohol-soluble portions after the second potassium hydroxide treatment in the case of the sulfite and kraft pulps were negligible and much larger starting quantities of raw materials would have been needed to warrant a quantitative recovery of this type of hemicellulose.

Hydrolysis of Sugar Ratio Determination

The Forest Products Laboratory method (*4*) was followed throughout this work. Only the hemicelluloses of the wood sample S_1 presented any difficulty in hydrolysis. The hydrolyzates were immediately neutralized with barium hydroxide solution to a pH of 5.3. The barium sulfate precipitate was removed and the hydrolyzates were concentrated *in vacuo* at approximately 45°C. These concentrates were preserved with toluene and stored at 0°C. They were regularly chromatographed within one day. For this purpose Whatman no. 1 paper that had been very shortly before washed twice for 24-hr. periods with distilled water was used. Between these two washings, the papers were always dried well for about 8 hr. As the developing agent, the mixture of ethyl acetate:pyridine:water (8:2:1) was used (*5*). The sugars were determined by the method of Timell, *et al.* (*6*). A Beckman DU spectrophotometer was used in the measurements of the optical densities.

Characterization of the Hemicelluloses and the Cellulosic Materials

Cupriethylenediamine of 0.5 *M* concentration was used as solvent for the viscosity determinations (*7*) and the limiting viscosity numbers of the purified hemicelluloses. The measurements were made with an Ubbelohde viscometer. The degree of polymerization in cupriethylenediamine was at first calculated using Conrad's constant (*8*):

$$D.P. = 190.5[\eta]_{C.E.D.}$$

The optical rotations were determined in 8% potassium hydroxide, with the addition of borate in the case of the potassium metaborate-extracted hemicellulose, and in 18% sodium hydroxide respectively, at concentrations of about 1%. The readings were made in 100-mm. tubes at temperatures between 21 to 23°C. in a Bausch & Lomb saccharimeter. Undissolved portions of the hemicelluloses were always removed by centrifugation, washed, solvent-exchanged, and dried *in vacuo* at 45°C. Their weights were determined for the calculation of concentrations as needed in the calculations of specific rotations.

The x-ray diffractograms of the hemicelluloses and of the cellulosic materials were taken by means of a Norelco para focused diffractometer, with a wide angle goniometer. Nickel-filtered copper x-radiation (λ = 1.5418 A.) was used. The tube was run at 35 kv. and 20 ma. and 1/4° divergence and receiving slits, and a 0.006-in. scattering slit were used in the diffractometer. A powder technique was employed, whereby the hemicellulose samples were loosely filled in the sample holder, and the cellulose samples were compressed into disks and held by special holders (*9*). All hemicelluloses showed evidence of crystallinity. All x-ray data were evaluated in the establishing of the relative value of an index of molecular order.

The hemicellulose sample of sprucewood, as obtained after the first potassium hydroxide treatment, was investigated also by electron microscopy. An aqueous dispersion was deposited on copper grids carrying a collodion film. After the deposition and drying of the hemicellulose, the grids were shadowed with chromium at an angle of 45° and viewed in an R.C.A. electron

Table I. Removal of Extractives from Ground Raw Materials

Loss, %, based on ovendry material

Sample	Solvent extn.	Aqueous extn.	Total	pH during extn.
S_1	2.36	2.90	5.26[a]	5.8
S_2	1.06	2.77	3.83	6.3
S_3	0.96	2.46	3.42	6.3
S_5	0.56	2.28	2.84	8.5

[a] In a previous determination a total loss of 4.95% was found (*2*).

Table II. Preparation of Chlorite Holocellulose

Sample	Chloriting, hr.	Used ovendry purified material, g.	Obtained ovendry holocellulose, g.	Yield, %
S_1	5	137.6	98.8[a]	71.8
S_2	3	99.4	96.5	97.1
S_3	3	112.2	107.9	96.2
S_5	4	109.2	104.1	95.2

[a] Klason lignin content 1.13%.

microscope, type EMU-3F, operated at 50 kv. at the magnifications of 16,000 and 32,000. Several micrographs were prepared.

RESULTS

All samples of the raw materials had been in storage since about spring, 1954. The permanganate numbers of samples S_2 and S_3 were, therefore, redetermined. Both numbers were now found lower, although not very significantly. S_2 had dropped from 12.8 to 12.4 and S_3 from 14.0 to 13.4. These determinations were made by the standard method (*10*).

The losses of material caused by the removal of extractives by the azeotropic ethanol:benzene mixture (1:2), followed by 95% ethanol, and by the subsequent, pH uncontrolled, cold water extraction are shown in Table I.

The extractives were not isolated. The losses experienced in the water extraction probably occur because the disintegration of the samples by the Wiley mill facilitated the removal of low molecular-weight fractions of polysaccharides and of noncarbohydrate material. At the prevailing pH conditions no hydrolytic breakdown of the materials would be expected.

The results of the preparation of chlorite holocellulose are shown in Table II.

The yields obtained are somewhat higher than obtained before (*2*). This can be explained to a certain degree by the effects of the added water extraction. The holocelluloses of the three pulp samples were practically white, and from their appearance one would judge that the delignification had been carried out properly, and that the higher yields were not obtained at the cost of lesser efficiency in the removal of impurities. The lignin content (1.13%) of sample S_1 is lower than the usual result from the chloriting procedure. Yields of hemicelluloses and residual cellulosic material obtained after each alkaline treatment are tabulated in Table III.

Somewhat higher, unaccounted losses were encountered in the case of sample S_1. The unaccounted losses of the sulfite pulp samples are also higher than from the kraft. These are probably losses arising from repeated handling in the evaporation, ion exchange, and washing. Satisfactory recoveries resulted from the three borate treatments. Higher unaccounted losses were found in the three sodium hydroxide treatments; this may be explained by the circumstance that only the alcohol-insoluble hemicelluloses from the first extraction were isolated. For the size of sample used, the amounts recoverable from the other extractions would not have warranted quantitative handling in filtration and washing. The results of the potassium hydroxide and potassium metaborate extractions compare well with those obtained in previous work (*2*).

The results of the chromatographic analyses of the hemicelluloses are given in Table IV. The composition is stated in percentages of the respective polysaccharide. The alcohol-soluble hemicelluloses were also analyzed. Table IV gives the fractions as obtained during dialysis. From the analysis of each hemicellulose an average monomeric molecular weight was calculated; it is also given in Table IV.

The progress charts in Figs. 1 to 3 provide more ready information as to the progressing ratio of (galactans + glucans):mannans:(arabans + xylans) as resulting during the individual treatments, for S_1, S_2, S_3, and S_5. In Figs. 12 to 14, the removal of mannan and xylan with each successive step is shown graphically.

The ash content of the isolated hemicelluloses was determined and these materials were repurified by washing with aqueous hydrochloric acid at a pH of 3.0 to further remove any cationic impurities. These

Table III. Yields on Hemicelluloses and Cellulosic Residues after the Alkaline Treatments

All Figures in %, based on ovendry holocellulose

	S_1				S_2				S_3				S_5			
Cellulosic residue, final			53.33				79.64				79.26				76.79	
Hemicelluloses, recovered, total			39.20				15.40				15.89				20.86	
Unaccounted, total			7.47				4.96				4.85				2.35	
Cellulosic residue obtained, after the																
1st KOH extn.			69.75				94.06				93.82				93.43	
3rd KOH extn.			66.59				91.01				91.77				89.05	
3rd KBO_2 extn.			59.51				85.00				86.04				84.57	
3rd NaOH extn.			53.33				79.64				79.26				76.79	
Hemicelluloses recovered, after the																
1st KOH extn.		26.31				5.64				6.09				9.57		
of which insol. in 70% ethanol	21.02				4.75				4.77				6.78			
sol. in 70% ethanol in dialyzate	2.77			0.57				0.59				0.66				
in diffusate	2.52	5.29		0.32	0.89			0.73	1.32			2.13	2.79			
2nd KOH extn.		0.74				0.31				0.30				0.37		
3rd KOH extn. and total in KOH treatments		0.36	27.41			0.20	6.15			0.20	6.59			0.19	10.13	
1st KBO_2 extn.		5.26				4.26				4 53				3 38		
2nd and 3rd KBO_2 extn. and total in KBO_2 treatments		1.63	6.89			0.88	5.14			0.93	5.46			0.74	4.12	
1st NaOH extn.			4.90				4.11				3.84				6.61	
Unaccounted, after the																
1st KOH extn.	5.73			0.30				0.09								
3 KOH extns.			6.00				2.84				1.64				0.82	
3 KBO_2 extns.			0.19				0.87				0.27				0.36	
3 NaOH extns.			1.28				1.25				2.94				1.17	

Table IV. Composition of the Isolated Hemicelluloses and Average Molecular Weight of the Monomer

No correction made for destruction of sugars during hydrolysis

Sample	Polysaccharide, %	KOH extns.				KBO₂ extns.		NaOH extn.
		Insol. in 70% in ethanol	1st Sol. in 70% in dialyzate	Ethanol in diffusate	2nd	3rd	1st	2nd and 3rd	1st
S_1	Galactan	14.0	25.5	13.6	13.4	10.7	3.6	4.4	2.0
	Glucan	9.9	13.9	27.1	21.8	23.2	19.8	20.5	54.5
	Mannan	21.7	34.3	16.0	43.8	51.3	75.4	72.8	41.3
	Araban	7.9	9.9	6.4	5.3	5.0	...	...	...
	Xylan	46.5	16.4	36.9	15.7	9.8	1.2	2.3	2.2
Av. mol. wt. of monomer		145.8	154.2	149.1	155.8	157.7	161.8	161.1	161.5
S_2	Galactan	...	13.9	8.5	...	...	...	...	...
	Glucan	10.6	27.4	19.1	43.8	38.8	23.4	27.4	72.7
	Mannan	16.5	39.6	37.9	14.3	39.1	75.6	71.2	23.5
	Araban	...	1.6	...	...	...	...	...	...
	Xylan	72.9	17.5	34.5	41.9	22.1	1.0	1.4	3.8
Av. mol. wt. of monomer		140.2	157.2	151.8	149.6	155.5	161.7	161.7	161.0
S_3	Galactan	...	4.8	9.6	...	...	...	...	...
	Glucan	13.2	24.5	38.7	32.1	50.9	23.4	26.4	74.9
	Mannan	13.8	41.5	30.1	16.4	24.2	75.2	72.1	20.8
	Araban	...	...	...	...	...	...	...	...
	Xylan	73.0	29.2	21.6	51.5	24.9	1.4	1.5	4.3
Av. mol. wt. of monomer		140.2	153.4	155.7	146.7	154.7	161.7	161.7	160.8
S_5	Galactan	4.2	7.7	10.8	4.1	5.8	2.2	4.0	3.7
	Glucan	6.1	13.5	24.7	23.8	33.9	19.4	21.6	66.0
	Mannan	9.7	36.9	32.4	11.1	19.4	76.1	70.7	23.5
	Araban	5.4	3.0	...	3.4	5.5	...	...	...
	Xylan	74.6	38.9	32.1	57.6	35.4	2.3	3.7	6.8
Av. mol. wt. of monomer		138.1	149.6	152.5	143.8	149.9	161.4	161.0	160.1

materials were then washed, solvent-exchanged, and dried in the same way as in their first isolation. The ash of these repurified hemicelluloses was again determined. Very negligible differences from the first determinations were found. The ash of the second determination was analyzed for potassium, sodium, and other constituents by flame-spectrophotometric measurements. For this the respective attachment of the Beckman DU spectrophotometer was used. The results of this work are described in Table V. The main ash components are potassium and sodium, respectively. A complete analysis was not made, but from general appearance, the ash probably contains also appreciable amounts of silica.

The hemicelluloses of the wood sample S_1 contained the highest ash content, which may indicate the presence of uronic acid residues. Generally, it was found that the removal of ash during the preparation of the extracts, as described in the experimental part, was efficient and repurification is unnecessary.

All hemicelluloses were soluble in 0.5 *M* cupriethylenediamine and cuprammonium hydroxide. All four samples of the first potassium hydroxide extraction were soluble in 8% potassium hydroxide solutions, at a concentration of about 1% at room temperature, to approximately 95%. The sample from S_1 dissolved to 94.5% already at a concentration of 1% in 2% potassium hydroxide solutions. The four hemicelluloses from the potassium metaborate treatment were only partially soluble in 8% potassium hydroxide, but they dissolved completely on the addition of boric acid. Finally, the four extracts after the sodium hydroxide extraction were practically insoluble in potassium hydroxide, and they dissolved in 17.5% sodium hydroxide as follows: Sample S_1 to 51%, S_2 to 73%, S_3 to 69%, and S_5 to 63%. The insoluble fractions dissolved readily in cuprammonium hydroxide, as described by Reeves (*11*). There were no viscosity measurements made on the latter residues.

The results of the viscosity measurements, i.e., viscosity and the limiting viscosity number are tabulated in Table VI. In order to calculate D.P. and molecular weight from the limiting viscosity number, a constant must be determined for each hemicellulose. Husemann (*15*) has calculated a K_m-value of 4.3×10^{-3} for a mannan component from spruce, but this was for cuprammonium solutions and one cannot be sure that the Conrad ratio (*8*) is valid for hemicelluloses. With the co-operation of Mr. H. A. Swenson and Dr. S. F. Kurath a light-scattering molecular weight of 45,000 and an ultracentrifuge sedimentation molecular weight of 42,000 (Archibald method) were determined on hemicellulose from the first potassium hydroxide extraction of S_1. The light-scattering value gives the following

Table V. Color of Ash, Ash Content,[a] Composition of Ash[b]

Hemicellulose extracted from	Color of ash	Ash content, %	Composition of ash, %			
			K_2O	Na_2O	CaO	MgO
S_1 after first KOH extn.	Tan	6.46	64.6	4.9		
after first KBO_2 extn.	Light brown	2.45	47.9	8.1	<1	<1
after first NaOH extn.	Brown	0.88	14.1	59.3		
S_2 after first KOH extn.	Grayish-white	3.30	47.3	5.3		
after first KBO_2 extn.	White	1.94	75.1	6.3	<1	<1
after first NaOH extn.	Gray	1.53	14.4	59.3		
S_3 after first KOH extn.	Grayish-white	4.48	50.6	8.8		
after first KBO_2 extn.	White	2.12	59.8	29.4	<1	<1
after first NaOH extn.	Gray	0.88	13.3	82.3		
S_5 after first KOH extn.	Light gray	1.76	73.8	18.5		
after first KBO_2 extn.	White	1.81	44.8	23.9	<1	<1
after first NaOH extn.	Light gray	0.80	6.6	64.1		

[a] Determined at 650 to 700°C.
[b] Determined with flame spectrophotometer.

Table VI. Viscosities,[a] Degree of Polymerization,[b] and Molecular Weights[c] of the Extracted Hemicelluloses

Sample	After 1st KOH extn. [η]	cp.	D.P.	M_W	After 1st KBO_2 extn. [η]	cp.	D.P.	M_W	After 1st NaOH extn. [η]	cp.	D.P.	M_W
S_1	0.52	1.55	308	45,000	0.43	1.50	254	41,000	0.60	1.60	355	57,300
S_2	0.34	1.43	201	28,000	0.25	1.38	148	23,900	0.61	1.59	361	58,100
S_3	0.34	1.43	201	28,000	0.25	1.38	148	23,900	0.54	1.57	319	51,300
S_5	0.67	1.65	396	54,600	0.34	1.44	201	32,400	0.63	1.63	373	59,700
					After 2nd and 3rd KBO_2 Extn.							
S_1	...	...	...	...	0.38	1.46	225	...	...	...	...	...

[a] Determined in 0.5% concn. in 0.5 *M* cupriethylenediamine.
[b] Calcd. by formula D.P. = 592 $[\eta]_{C.E.D.}$
[c] Calcd. from the respective average monomer molecular weight.

equation for the material (using the average monomer weight of 145.8):

$$\text{(Weight average) } D.P. = 592[\eta]_{C.E.D.}$$

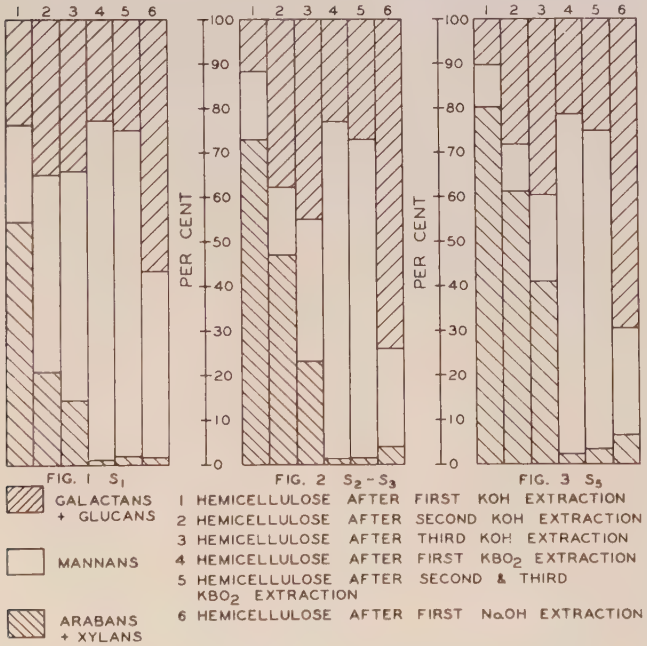
This is based on the assumption that a (in the equation $[\eta] = KM^a$) is approximately unity, which may not be as good an assumption with the hemicellulose as with cellulose. For calculating D.P.'s of our other hemicelluloses, we have preferred to use this value rather than the number-average D.P. of Husemann (*15*), recognizing that in either case there is error involved in going from one hemicellulose to another. The results of these calculations are given also in Table VI.

Here it also should be mentioned that a hemicellulose of slash pine (*Pinus elliottii*) was investigated. This extract had been prepared by extraction of pine holocellulose with 10% KOH. Because of a rather high ash content of the extract, the hemicellulose was washed in aqueous HCl at a pH of 3.0, and dried by solvent exchange and at 45°C. *in vacuo*. The ash content of this material was found to be 6.21%. The sugar ratio was determined in the same way as with the other hemicelluloses discussed here; in the following results the uronic acid content is expressed as glucose.

Sugar ratio of the slash pine hemicellulose:

Uronic acid anhydride	10.8%
Galactans	4.7%
Glucans	7.3%
Mannans	19.7%
Arabans	7.4%
Xylans	50.1%

The calculated average molecular weight of the monomer amounts to 144.8. This hemicellulose is soluble in water. Its limiting viscosity number was found to be 0.61, and the viscosity 1.59 cp. Average molecular weights of 35,000 and 40,000 were found by light scattering and ultracentrifugation, respectively. The dependence of the constant for calculation of D.P. on the origin and composition of the hemicellulose extracts becomes obvious when comparing the above results.



Figs. 1–3. Polysaccharide ratios of hemicelluloses

Table VI may be revised as new evidence becomes available.

The results of the x-ray diffraction investigations are shown in Table VII for the hemicelluloses, and in Table VIII for the cellulosic material. The x-ray investigations show that each extractant removes a different hemicellulose. This becomes obvious when comparing data of interplanar spacings (d) of the specific hemicelluloses and their indices of molecular order. The latter appears to be somewhat related to the chemical composition of the extracts, although it should be mentioned here again, that this represents a relative value only. The calculation of the index was done by dividing the difference between the observed maximal and the $2\theta = 28°$ intensity of diffraction by the maximal intensity, expressing this ratio as a percentage. The respective data obtained on the

Table VII. X-ray Diffraction Data on Hemicellulose[a,b]

Sample	θ, deg.	Relative intensity	Width at half ht., deg.	d, A	Index of mol. order, %
	After First KOH Extn.				
S_1	19.20	36.9	20.8	4.619	54
S_2	19.00	20.0	25.4	4.667	69
S_3	19.25	51.5	19.5	4.603	65
S_5	18.75	35.2	18.5	4.728	70
	After 3 KOH- and First KBO_2 Extn.				
S_1	12.20	45.50	3.5	7.240	74
	20.65	57.8	6.8	4.297	
S_2	12.2	18.5	5.5	7.240	77
	15.8	18.8	3.8	5.604	
	20.8	28.3	4.0	4.267	
S_3	12.1	37.0	4.5	7.308	79
	16.0	35.9	2.5	5.552	
	20.8	45.5	5.0	4.267	
S_5	12.0	22.2	6.3	7.369	75
	20.9	28.4	6.2	4.247	
	After 3 KOH-, 3 KBO_2-, and First NaOH Extn.				
S_1	20.3	15.4	10.0	4.381	71
S_2	12.8	37.5	6.2	6.910	75
	20.2	62.8	14.0	4.392	
S_3	12.1	39.3	7.6	7.308	77
	20.2	71.0	13.2	4.392	
S_5	12.0	23.6	6.8	7.369	69
	20.1	41.5	13.4	4.414	

[a] Diffraction computed by means of the Brigg equation

$$\lambda = 2d \sin \theta$$

λ = wavelength of x-radiation used
d = interplanar spacing
θ = diffraction angle

[b] Powdered hemicellulose samples were passed through an 80-mesh screen and placed directly in the sample holder. Data are computed on the basis of width at half height.

Table VIII. X-ray Diffraction Data of Cellulosic Materials[a,b,c]

Sample	2θ, deg.	Rel. intensity	Width at half ht., deg.	d, A	Index of mol. order, %
1. Ground, Extractive-Free Raw Materials					
S_1	15.1	27.5	18.0	5.862	79
	22.3	32.0	10.5	3.983	
S_2	15.2	30.5	16.0	5.829	87
	22.3	50.5	9.8	3.983	
S_3	15.2	38.3	17.0	5.829	84
	22.3	52.0	11.0	3.983	
S_5	15.8	17.5	15.5	5.604	74
	22.2	27.4	9.0	3.997	
2. Chlorite Holocelluloses					
S_1	15.2	15.3	17.0	5.824	66
	22.3	22.2	11.8	3.983	
S_2	15.2	16.5	14.7	5.824	84
	22.3	27.2	9.0	3.983	
S_3	15.2	33.5	18.0	5.824	84
	22.3	55.5	10.4	3.883	
S_5	15.8	30.8	16.3	5.604	87
	22.3	47.1	9.5	3.983	
3. Cellulosic Residues after First KOH Extn.					
S_1	16.1	36.5	16.2	5.500	82
	22.3	45.8	16.2	3.983	
S_2	15.0	19.8	11.0	5.901	81
	22.1	30.0	16.7	4.019	
S_3	15.0	15.0	6.2	5.901	80
	22.2	20.5	17.7	4.009	
S_5	15.0	...	...	5.901	75
	22.1	13.0	16.8	4.019	
4. Cellulosic Residues after 3 KOH, 3 KBO_2, and 3 NaOH Extns.					
S_1	12.2	19.5	6.5	7.248	83
	20.0	34.0	5.0	4.436	
	22.0	33.8	6.3	4.037	
S_2	12.0	11.9	8.5	7.369	81
	20.0	20.7	5.5	4.436	
	21.9	20.3	6.5	4.055	
S_3	12.1	23.4	7.5	7.308	80
	20.1	42.0	4.4	4.414	
	22.0	44.0	6.0	4.037	
S_5	12.1	22.5	6.0	7.308	79
	20.1	36.3	5.8	4.414	
	22.0	36.8	9.0	4.037	

[a] All samples were airdried from aqueous washings.
[b] Diffraction is computed in the same way as in Table VII.
[c] 0.5 g. powdered cellulosic airdried material, that had been ground before purification, was compressed into disks of 1 in. diam. under a pressure of 6000 p.s.i.; this procedure was otherwise similar to that reported by Segal, *et al.* (*9*).

cellulosic starting material are also interesting. Here it should be mentioned that all cellulosic material in this investigation was redried from the water-washed state by air drying only. It can be assumed, therefore, that no thermally induced effects on the x-ray patterns occurred during drying. It can be seen from the results of Table VIII that the lattice pattern of the cellulosic materials had changed after the first extraction with sodium hydroxide where the data of the changed lattice pattern indicate a radical change to the cellulose II pattern. For the sake of informative comparison the diffractograms of the hemicelluloses of the four samples as obtained by the three different extractants as well as the diffractograms of the original materials, their holocelluloses and their residues after the first potassium and the first sodium hydroxide treatments were traced in combined plots, as shown in Figs. 4 to 11.

Table IX. Specific Rotations and Molecular Rotations[a] of Hemicelluloses

Sample	After 1st KOH extn. dissolved in 10% KOH $[\alpha]_D^{21}$	After 1st KOH extn. dissolved in 10% KOH $[\alpha_M]_D^{21}$	After 1st KBO_2 extn. dissolved in alk. borate soln. $[\alpha]_D^{21}$	After 1st KBO_2 extn. dissolved in alk. borate soln. $[\alpha_M]_D^{21}$	After 1st NaOH extn. dissolved in 17% NaOH $[\alpha]_D^{23}$	After 1st NaOH extn. dissolved in 17% NaOH $[\alpha_M]_D^{23}$
S_1	−40.7	−59.3	−65.8	−106.5	−78.4	−126.6
S_2	−77.4	−108.5	−72.7	−117.6	−21.3	−34.3
S_3	−78.9	−110.6	−74.4	−120.3	−22.6	−36.3
S_5	−108.2	−149.4	−79.6	−128.5	−46.4	−74.3

[a] Calcd. by formula $[\alpha_M] = (M/100)[\alpha]$.

The specific and molecular rotations are compiled in Table IX. Possible effects of the three different solvents on the optical rotation should be considered, especially the enhancing action of alkaline borate. The optical rotation of xylans and glucomannans on spruce, pine, western hemlock, and other coniferous woods and on their pulps have been reported by several researchers (*12*, *21*, *22*). Compilation of such values can be found also in Whistler and Smart (*23*) and Polglase (*20*).

Finally, Table X shows what percentages of mannans and xylans were isolated in each alkaline treatment. The sum of the total polysaccharide in each hemicellulose was set as 100. This table is helpful in the interpretation of the efficiencies of the individual alkaline treatments; it was used in tracing the graphs of Figs. 12 to 14. For instance, one can see that in the case of the hemicellulose of kraft, as extracted by the third potassium hydroxide treatment, only 0.59% of the total mannans extracted were contained in this particular fraction; the high mannan content (19.4%) still does not make such a small fraction important.

Figures 15 and 16 are electronmicrographs showing the hemicellulose extracted from Sample S_1 by the first treatment with potassium hydroxide. The magnifications as taken with the electron microscope were 16,000 and 32,000, respectively, and in the figures the actual magnifications are 36,000 for Fig. 15, and 73,200 for Fig. 16. As shown in Table VI, this hemicellulose has a D.P. of 308 and it has the lowest relative index of molecular order (Table VII).

Table X. Mannan and Xylan Distribution, Per Cent of Total Recovered Polysaccharides

% Hemicellulose extracted by	Mannose S_1	Mannose S_2	Mannose S_3	Mannose S_5	Xylose S_1	Xylose S_2	Xylose S_3	Xylose S_5
1st KOH, alc. insol.	33.54	12.92	10.79	10.42	84.87	85.34	81.79	78.69
1st KOH, alc. sol.	6.89	3.73	4.02	3.85	3.94	2.46	4.04	3.98
1st KOH, alc. sol.	2.96	1.99	3.61	10.92	8.08	2.71	3.71	10.64
1st KOH extn.	43.49	18.64	18.42	25.19	96.89	90.51	89.55	93.31
2nd KOH extn.	2.38	0.73	0.80	0.65	1.00	3.21	3.62	3.31
3rd KOH extn.	1.35	1.28	0.78	0.59	0.33	1.08	1.15	1.04
KOH—total	47.22	20.66	20.01	26.42	98 19	94.80	94.32	97.66
1st KBO_2 extn.	29.17	53.09	55.89	40.72	0.54	1.06	1.48	1.21
2 and 3 KBO_2 extn.	8.73	10.32	10.99	8.28	0 32	0.30	0.33	0.42
KBO_2—total	37.90	63.41	66.88	49.00	0.86	1.36	1.81	1.63
NaOH	14.88	15.93	13.11	24.58	0.95	3.84	3.87	0.71

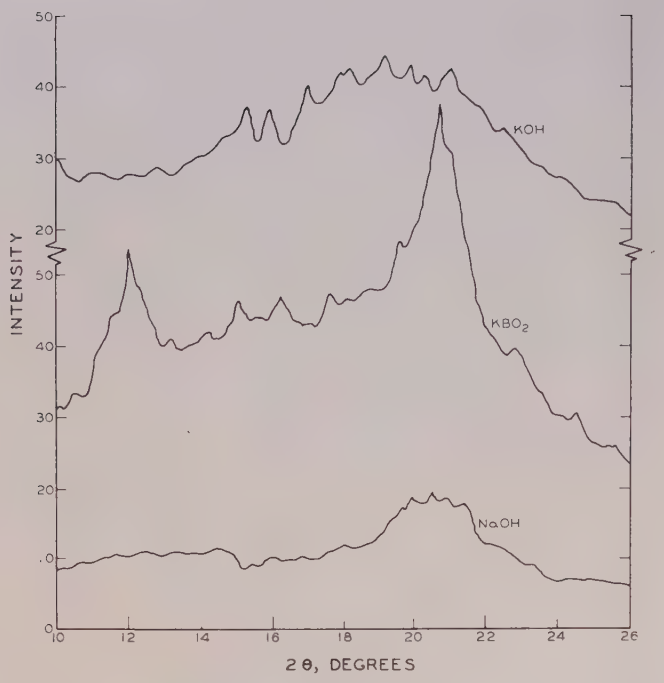


Fig. 4. X-ray diffractogram of hemicellulose of sprucewood (S_1)

DISCUSSION AND CONCLUSIONS

The results of this investigation show that the sequential use of potassium hydroxide, potassium hydroxide and potassium metaborate, and sodium hydroxide as extractants selectively removes hemicelluloses from sprucewood, sulfite, and kraft pulps. The sodium hydroxide removes a certain glucose-rich glucomannan fraction containing some xylan residues which apparently had resisted the prior extractants.

This material extracted with sodium hydroxide may be a mixture of the same glucomannan extracted by potassium borate with a glucan of some sort or it may be a different type of glucomannan. Until we have carried out fractionation studies we shall not know. On account of the high-viscosity determinations, however, we doubt that degradation during the sodium hydroxide extraction is involved, although cellulose breakdown products of this molecular size might possibly occur.

Even during oxygen-free extracting conditions, changes are known to occur in the polysaccharides which might affect the solubilities and thus reduce the ease of isolation of chemically homogeneous hemicelluloses (*13*). This may explain the retention of small amounts of hemicelluloses after the complete extraction sequence, but much more information is needed before such an assumption can be justified. The question

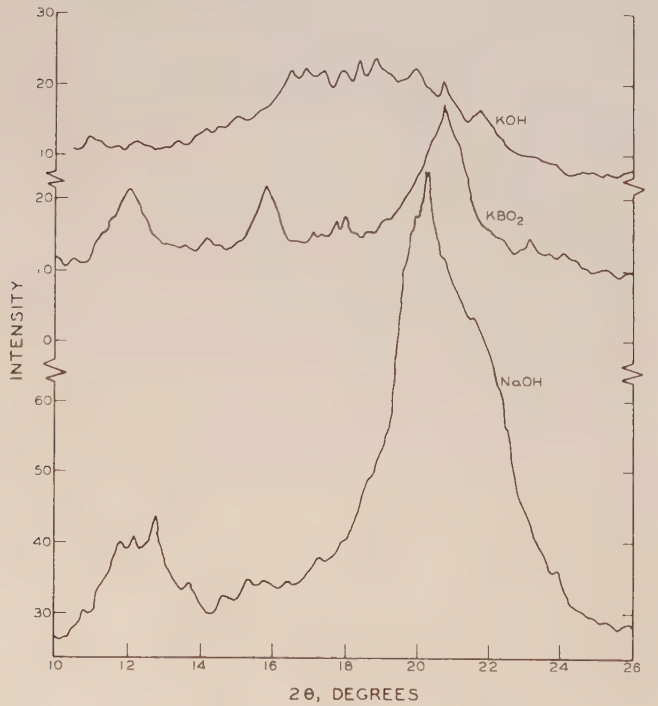


Fig. 5. X-ray diffractogram of hemicellulose of sulfite pulp (S_2)

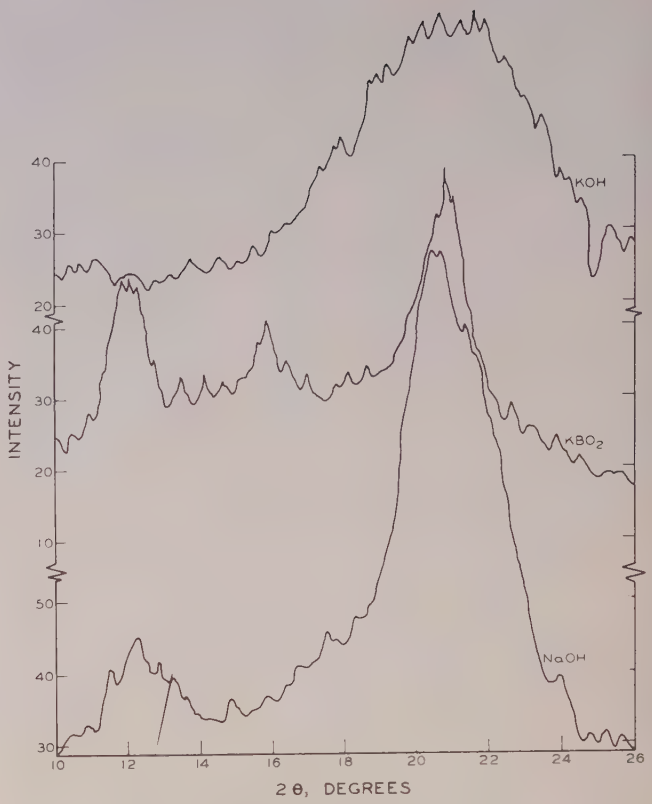


Fig. 6. X-ray diffractogram of hemicellulose of sulfite pulp (S_3)

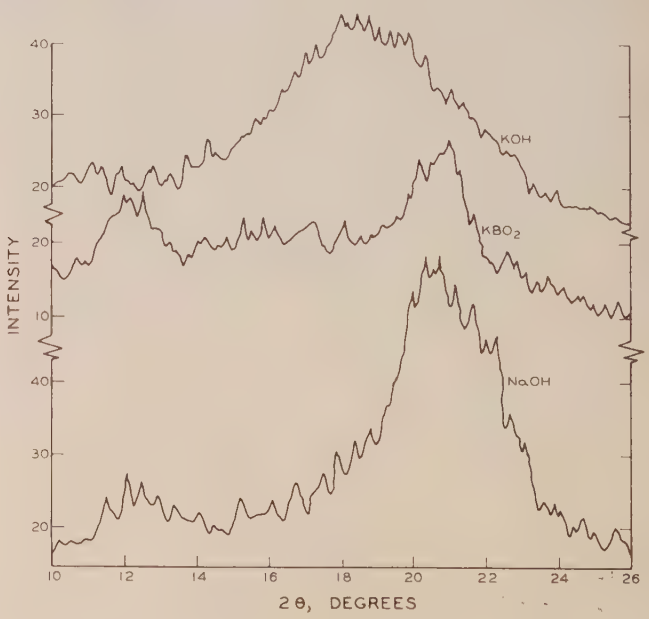


Fig. 7. X-ray diffractogram of hemicellulose of kraft (S_5)

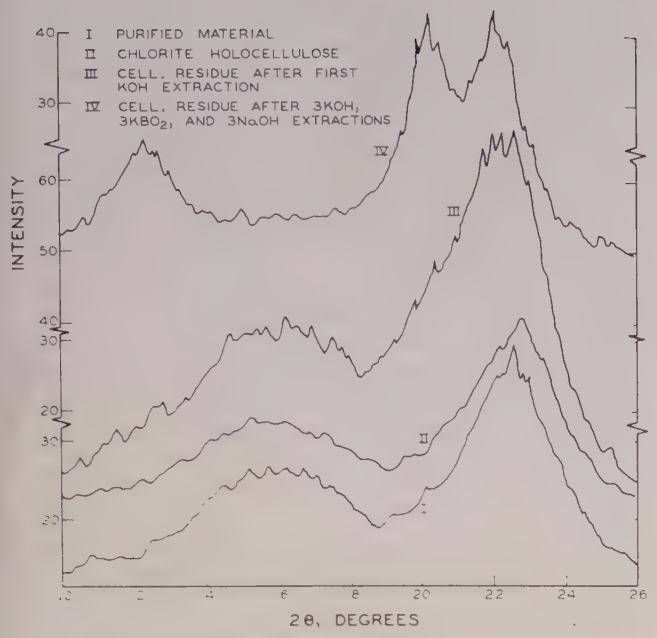

I PURIFIED MATERIAL
II CHLORITE HOLOCELLULOSE
III CELL. RESIDUE AFTER FIRST KOH EXTRACTION
IV CELL. RESIDUE AFTER 3KOH, 3KBO2, AND 3NaOH EXTRACTIONS
INTENSITY
2θ, DEGREES

Fig. 8. X-ray diffractogram of sprucewood (S_1)

also arises how efficiently by means of a certain arrangement of extractants the removal of hemicelluloses from cellulosic materials can be performed. While it was not the aim of this investigation to work out optimal extraction conditions, the reported data permit us to discuss, to a certain degree, the efficiency of removal that was achieved. The xylan content of the isolated hemicelluloses decreases rather rapidly with progressive potassium hydroxide treatments; over 93% of the xylans are removed by the first potassium hydroxide treatment. The comparison of the three hemicelluloses shows that those from the wood have lower xylan contents than those from the two types of pulps; also, the decrease of the xylan ratio in the three potassium hydroxide treatments is more pronounced in the wood

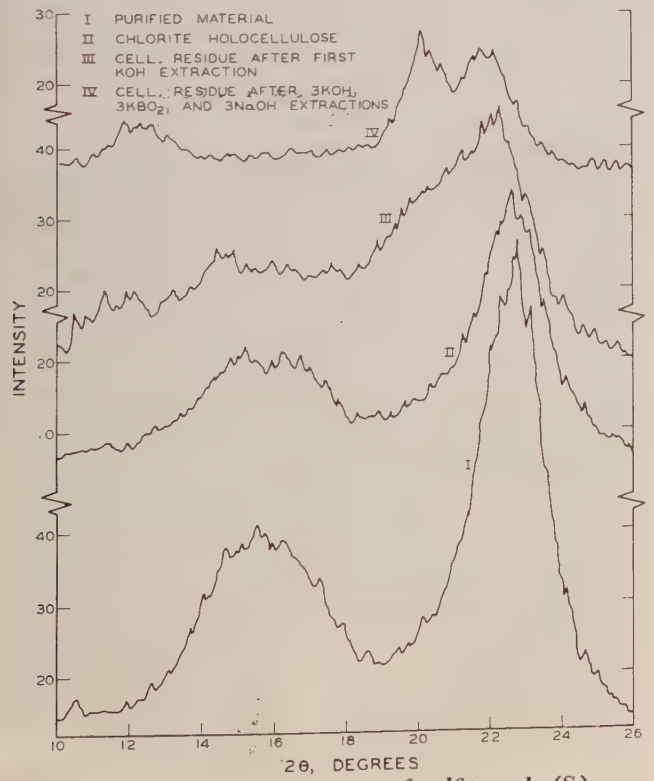

I PURIFIED MATERIAL
II CHLORITE HOLOCELLULOSE
III CELL. RESIDUE AFTER FIRST KOH EXTRACTION
IV CELL. RESIDUE AFTER 3KOH, 3KBO2, AND 3NaOH EXTRACTIONS
INTENSITY
2θ, DEGREES

Fig. 9. X-ray diffractogram of sulfite pulp (S_2)

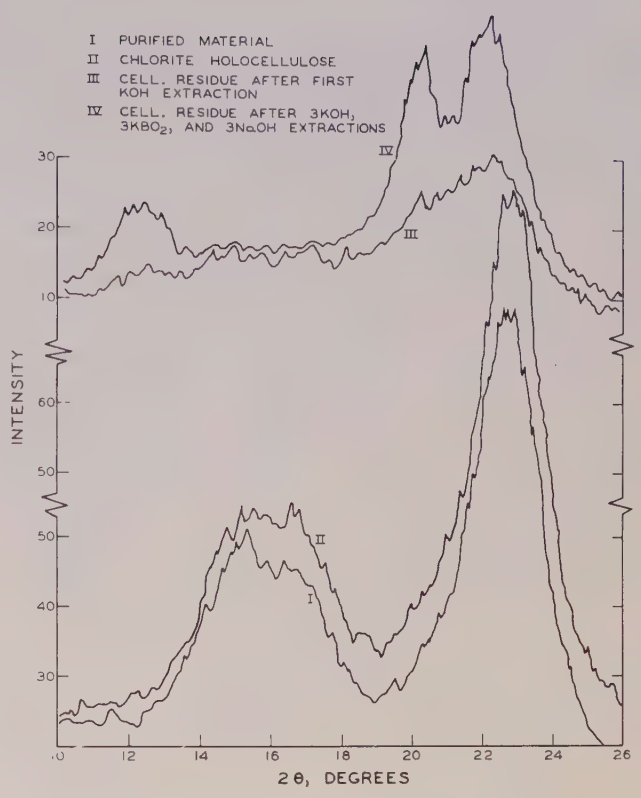

I PURIFIED MATERIAL
II CHLORITE HOLOCELLULOSE
III CELL. RESIDUE AFTER FIRST KOH EXTRACTION
IV CELL. RESIDUE AFTER 3KOH, 3KBO2, AND 3NaOH EXTRACTIONS
INTENSITY
2θ, DEGREES

Fig. 10. X-ray diffractogram of sulfite pulp (S_3)

sample. Slightly increased xylan contents appear in the sodium hydroxide than in the potassium metaborate hemicelluloses, being the highest in kraft. Furthermore, it can be concluded that the sugar ratios of the potassium metaborate-extracted hemicelluloses are the same in all three types of materials for successive treatments. Finally, it can be concluded that a glucose-rich glucomannan results from the sodium hydroxide treatment; the wood sample shows a higher mannan ratio than either of the two types of pulps, as

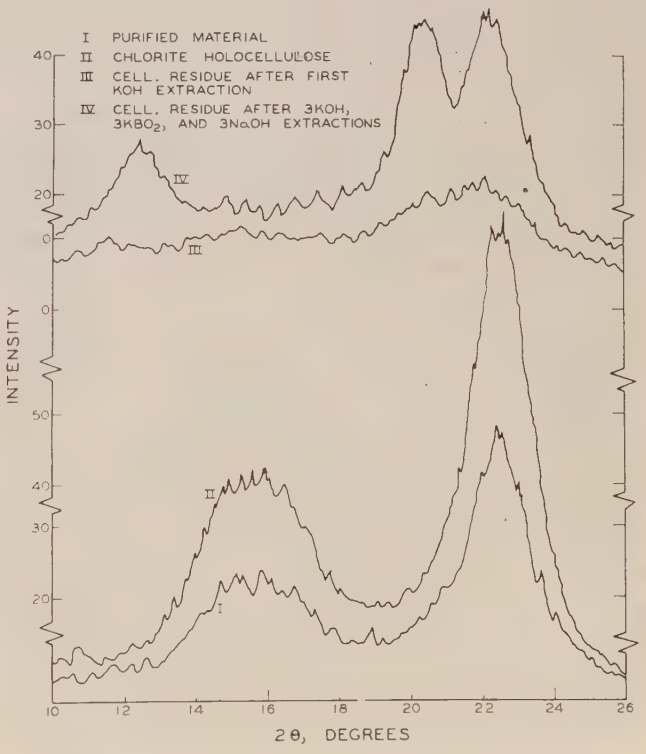
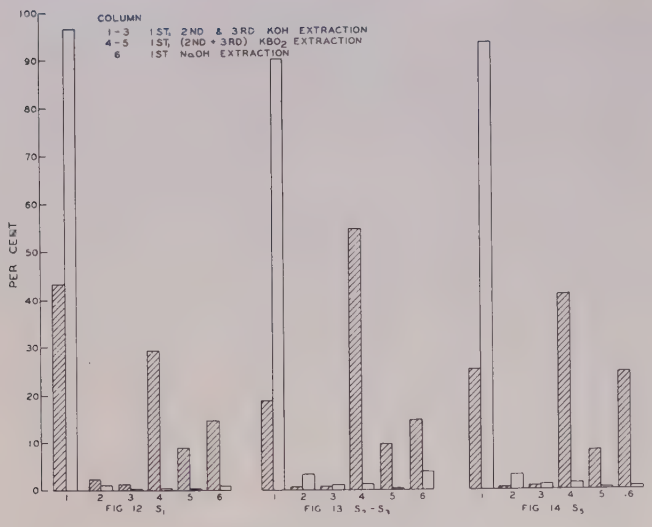

I PURIFIED MATERIAL
II CHLORITE HOLOCELLULOSE
III CELL. RESIDUE AFTER FIRST KOH EXTRACTION
IV CELL. RESIDUE AFTER 3KOH, 3KBO2, AND 3NaOH EXTRACTIONS
INTENSITY
2θ, DEGREES

Fig. 11. X-ray diffractogram of kraft pulp (S_5)



Figs. 12–14. Mannans and xylans recovered in the individual six extraction steps[a,b]. [a]Based on the total polysaccharides extracted. [b]Mannans-left, hatched column; xylans-right, plain column

was also the case in the alcohol-insoluble potassium hydroxide hemicelluloses.

Sprucewood (*Picea excelsa*) and sulfite pulp hemicelluloses of a chemically more homogeneous composition were reported by Hägglund, *et al.* (*14*). This group obtained hemicelluloses of high xylan contents by extracting wood holocellulose with dimethylsulfoxide at room temperature; and the sugar ratio (galactose + glucose):mannose:(arabinose + xylose) of 3.3:0.8:5.9, compares with our results of 2.3:2.2:5.5 in the case of the first potassium hydroxide treatment. The same extractant used with sulfite pulp permitted them to isolate extracts of the respective sugar ratios of 0.3:(+):9.7, as compared with the ratio obtained in this work of 1.2:1.5:8.0. These investigators apparently did not investigate viscosity and molecular weight data on the materials they had obtained.

Husemann (*15*) prepared a spruce mannan by oxygen-free extraction of wood holocellulose with 17% sodium hydroxide. No analysis of the resulting hemicellulose except the methoxyl content of 1.26% and the specific rotation of $[\alpha]_D$ −32° in 6% sodium hydroxide are given. Her viscometric and osmometric determinations indicated a D.P. of 160. In our previous investigations with 12% sodium hydroxide (*1*, *2*) extracts of 20 to 25% pentosan content were isolated.

Wethern (*16*) delignified sprucewood under very mild conditions and extracted the holocellulose successively with 5 and 16% potassium hydroxide. The glucan:mannan:xylan ratios of two hemicelluloses are 1.5:1.1:7.4 and 1.5:3.1:5.4, respectively. For comparison, the hemicellulose extracted in the present work with 16.7% potassium hydroxide, ran 2.3:2.2:5.5. For approximately the same xylan content, our material has about twice the glucose:mannose ratio of Wethern's second hemicellulose. Wethern did not determine lignin, but it was probably much higher than in our samples on account of the mild delignification procedure (the observed brown color of his alkaline extracts seems to bear this out). The mildness of the holocellulose preparation is probably also responsible for the higher limiting viscosity number, 0.97, as compared to our 0.52. His yields are also about half of ours. It is interesting to speculate on the possible role of lignin-hemicellulose compounds in reducing the yields. Our low lignin pulp also yields a higher glucose and xylose ratio (compared to mannose) and this may be a slight indication that these two sugars are preferentially present in any lignin-bound hemicelluloses, but there is no real evidence of this. Wethern reports D.P. values of 120 to 160, based on osmometry of the butyrates.

Clermont (*17*) also prepared his holocellulose under milder conditions than in the present investigation. The holocellulose contained some 10.6% lignin, far more than in this investigation. He extracted this with hot water, 5 and 16% potassium hydroxide, and after a chlorination step, again with 16% potassium hydroxide. The total yield amounted to some 16%, whereas 27% were obtained in the present work. No direct comparison of the sugar ratio is possible, since he does not give any analysis of the unfractionated hemicellulosic material. Using a K value of 4.4×10^{-3} for pentosans and 5.4×10^{-3} for hexosans for the solute-solvent system with 10% potassium hydroxide as solvent he arrives at D.P. values in the range of 57 to 175.

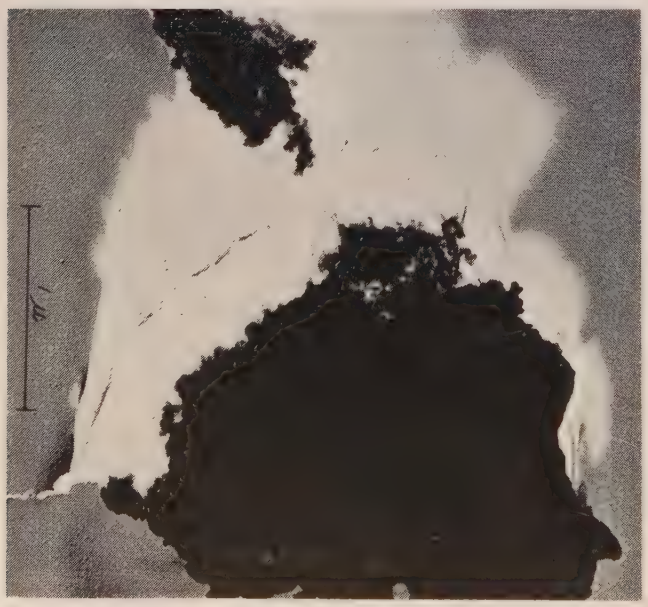


Fig. 15. Sprucewood hemicellulose extracted from chlorite holocellulose with 3.9 N KOH. Chromium shadowed

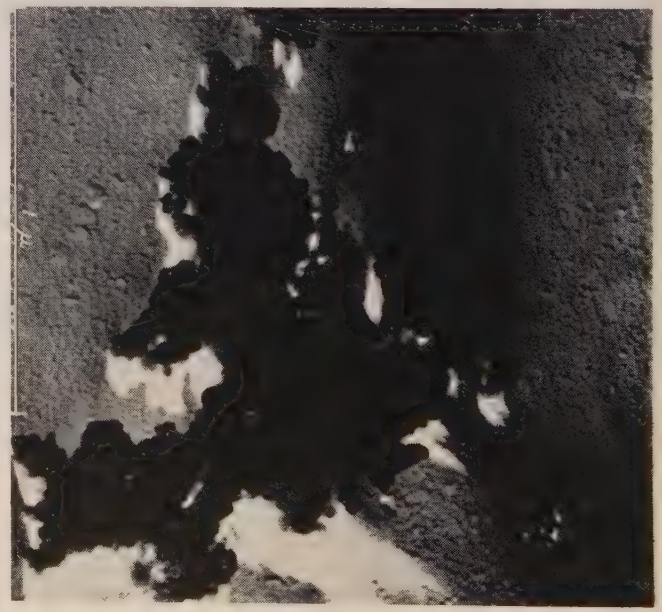


Fig. 16. Sprucewood hemicellulose extracted from chlorite holocellulose with 3.9 N KOH. Chromium shadowed

Timell and Tyminski (*18*) delignified spruce by the same method used in the present investigation, and obtained a holocellulose of 11.8% pentosan content. This compares well with the previously obtained value of 11.5% xylose and arabinose in the sugars from our sample of sprucewood holocellulose (*2*). They extracted with 17.5% sodium hydroxide with 4% added boric acid, and obtained a crude glucomannan with a sugar ratio (galactans + glucans):mannans:(arabans + xylans) of 2.3:7.3:0.4 at a yield of 11.2% of the original wood or about 16% on holocellulose. On precipitation with Fehling's solution, they removed all minor sugars and obtained the glucomannan with the glucan:mannan ratio of 1:3.18, which became 1:3.0 on further purification, and a limiting viscosity number of 0.24. These values compare well with those obtained by us on unpurified potassium metaborate hemicellulose from sulfite pulps.

Merler and Wise (*19*) report on a glucomannan with the sugar ratio glucose:mannose:xylose of 1.7:7.8:0.3, which had been prepared from an undissolved copper complex on extraction of sulfite pulp with cuprammonium hydroxide. The molecular weight distribution of about three-fifths of the total lies between 15,000 and 22,000, as determined by ultracentrifugation.

Even though certain changes may occur during the oxygen-free alkaline isolation of hemicelluloses this method is the most common for removing polysaccharides from holocelluloses (*13*). Only rarely is extraction under other conditions, as in the presence of reducing agents, reported. The existing difficulties in setting up specific and uniform methods for both the preparation of holocellulose and the alkaline extraction of hemicelluloses will inevitably limit the degree of possible comparison and evaluation of research data. These drawbacks become apparent from the above attempt to compare published data.

In the isolation of hemicellulose from spruce the more readily extractable xylans can be removed preferentially. For this purpose, potassium hydroxide appears to be a more suitable extractant than sodium hydroxide or combinations with borates (*2*). The subsequent removal of glucomannans of sugar ratios of glucans:mannans of 1:3.0 by means of potassium metaborate treatments appears to be highly selective, especially in the first extraction.

The nature of the xylose-containing carbohydrate in the sodium hydroxide-extracted material poses an interesting question. It may differ chemically from that removed by potassium hydroxide or it may have been altered by the potassium hydroxide so as to be rendered more resistant. The difference may also be morphological. We cannot answer this question without further information, perhaps from fractionation.

Although the constant developed in this work for converting viscosity to D.P. was determined on a hemicellulose which was only partially fractionated, it is believed that it is still more suitable for evaluating the potassium hydroxide-extracted material (largely xylans) than the similar constants which had been used. The reasons for this have already been indicated. Perhaps it need not be emphasized that the constant must eventually be determined for the pure fractionated compounds.

Although there is considerable data on the rotations of hemicelluloses of coniferous origin (*12*, *15*, *20–23*), relatively little of this applies to those from spruce (*15*, *22*). The values for glucomannans from spruce range from −37° to −44°C. in sodium hydroxide solution which agree reasonably well with the values in sodium hydroxide solutions for the hemicelluloses extracted with sodium hydroxide from sulfite pulps in Table IX, −34.3° and −36.3°C. Since we ran rotations in the solutions used for extraction, only this series is comparable. If this work is repeated, an effort will be made to compare rotations in the same solvent, perhaps sodium hydroxide solution (potassium hydroxide does not dissolve the borate-extracted substance and the effect of borates on the rotation makes this choice of solvent undesirable).

The rotations of the hemicelluloses from wood, sulfite pulp, and kraft are, in general, different. In particular, the rotation of the potassium hydroxide hemicellulose from sprucewood is lower than that from the sulfite pulp which is lower than that from kraft pulp, a relationship also observed by Hamilton, *et al.* (*21*), for western hemlock and southern pine.

The preliminary results with the electron microscope indicate the presence of what appears to be hexagonal platelets in the wood hemicellulose extracted by potassium hydroxide. This is the form of the crystals of Yundt's (*24*) crystalline xylan. This is additional evidence perhaps that Yundt's crystallizing procedure was a true purification and did not involve any major chemical change.

The electronmicrographs show some similarity to those of Rånby (*30*) and of Treiber's beech xylan (*29*), and a comparison of the extracted and unextracted holocelluloses might be of interest. Electronmicrographs of fractionated materials are also needed and are being made.

The crystalline x-ray pattern of hemicellulose has been noted by other workers. The xylans have been more frequently studied (*24–31*) than the glucomannans (*32–34*); these two are quite different in pattern. The present investigators had hoped that the diffraction patterns might serve as a means of distinguishing between the different hemicelluloses. This proved true in regard to the potassium hydroxide extract, which is quite different from the others. The similarity of glucomannan fractions from different sources has already been pointed out by Lindberg and Meier (*32*). Our borate fraction is practically pure glucomannan. The patterns of this and of the sodium hydroxide fraction are somewhat similar to that of cellulose II.

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Some New Developments in Synthetic Fiber Paper

R. A. A. HENTSCHEL

Binders have been shown to be the key to the successful commercial production of synthetic fiber products on papermaking equipment. Du Pont has developed a new form of binder, identified as a fibrid, specifically designed for synthetic fibers. Fibrids have a morphology similar to wood pulp. When they are combined with synthetic fibers in the feed to the headbox, they contribute high wet waterleaf strength for operability on the paper machine. Since fibrids can be made from a wide variety of polymers, they can be made chemically similar to the fiber which is to be bonded. This permits full utilization of the inherent strength and chemical properties of the synthetic fibers. By combining the various commercially available fibers with appropriate fibrids in a variety of ways, a wide range of products can be made. Thus structures can readily be tailored to meet specific end-use requirements.

Past work with synthetic fibers in paper has pointed out that these fibers have no inherent bonding power and that separate binders must therefore be used to tie the fibers together (*1*). The binders which were available in the past were primarily vinyl polymers applied from dispersions to the fiber web after it was formed on the wire. These systems were deficient in two respects. Firstly, the binders, being chemically dissimilar from the fibers, did not develop the full chemical and physical property potentials of the synthetic fibers. Secondly, the fiber webs, having very low strength as formed, were very difficult to handle on the paper machine. Clearly, a new binder system was needed, designed specifically for the synthetic fibers, which could be added to the paper machine furnish and which would overcome these problems. In effect, the need was for a synthetic analog of wood pulp. Du Pont has developed a new family of binders which now meet these needs. This new binder system has been given the generic name "fibrid" to identify it, and products made from fibrids and synthetic fibers on papermaking equipment have been given the generic name of "textryl." These names will be used subsequently in this paper.

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FIBRID BINDER SYSTEM

Fibrids are fibrous synthetic polymer particles whose morphology is somewhat similar to beaten wood pulp. Because of their form, when combined with synthetic fibers, they give a furnish which behaves very much like conventional pulps on the paper machine. The wet-web strength of the waterleaf as laid down on the wire is roughly the same as that of a kraft waterleaf. When the webs are dried, they develop adequate dry-sheet strength for winding up and subsequent handling. Full sheet strength is developed by a hot calendering operation on the dried sheet in which the binder is fused. Fibrids can be made from virtually any synthetic polymer. It is therefore possible to prepare fibrids which are chemically similar to the fibers which they are to bond. In this way, fibrids can be prepared which develop the full strength potentials of the synthetic fiber and which, giving a chemically homogeneous textryl, permit advantage to be taken of the chemical inertness of the fiber. Figure 1 shows a photomicrograph of a typical fibrid and Fig. 2, an uncalendered fiber–fibrid textryl. A selected series of fibrids is available in limited quantities, tailored for polyester, polyamide, and acrylic fibers. Extensive patent coverage has been applied for on these new products.

CALENDERED FIBRID-BONDED SHEET PROPERTIES

Synthetic fiber–fibrid systems have been extensively studied over a wide range of fibers. The theoretical aspects of structure–property relationships for synthetic fiber papers in general were discussed in an earlier publication (*2*). Most of the conclusions drawn in that publication were based on fibrid bonding systems; but were discussed in general terms without reference to specific fibers or fibrids. This paper will

Fig. 1. Photomicrograph of 201 fibrids. Magnification ×250

Fig. 2. Photomicrograph of textryl of Dacron fiber and 201 fibrids. Magnification ×50

give numerical data for Dacron® polyester fibers, nylon, and Orlon® acrylic fibers bonded with appropriate fibrid systems. The Dacron polyester fiber system bonded with a polyester fibrid coded 201 will be discussed first in some detail as a typical example. Similar detailed information, only summarized in this paper, has been developed for textryls made from nylon, and Orlon acrylic fibers and their corresponding fibrids.

TEXTRYLS FROM DACRON POLYESTER FIBER

Physical Properties

Effect of Binder Content. The first variable to be discussed for the Dacron polyester fiber textryl is the binder content and its effect on physical properties. Figure 3 shows the relationship of binder content to tensile strength for a textryl made from $^1/_4$ in. 3-denier fiber and calendered at 400°F. Curves are given for dry strength and wet strength at room temperature, and wet strength at 194°F. (90°C.). Tensile strength is normalized for sheet weight and is given in lb. per in. per oz. per sq. yd. These tensile strengths can be converted to conventional lb. per in. units for any specified basis weight by multiplying by (basis weight/19.8), since 1 oz. per sq. yd. equals 19.8 lb. basis weight, TAPPI Standard ream. However, this conversion must be used with caution at very low basis weights as will be shown later. As the fibrid content of the textryl increases, the strength increases to a maximum of about 16 lb. per in. per oz. per sq. yd. at about 30% fibrid and then falls off. Since Dacron polyester fibers are highly hydrophobic, the wet strength is only slightly lower than the dry strength, at 15 lb. per in. per oz. per sq. yd. At 90°C. the wet textryl still retains over 60% of its dry strength.

Figure 4 shows the tear and burst strengths as a function of binder content. These values are again nor-

® Dacron is Du Pont's registered trademark for its polyester fiber. Orlon is du Pont's registered trademark for its acrylic fiber.

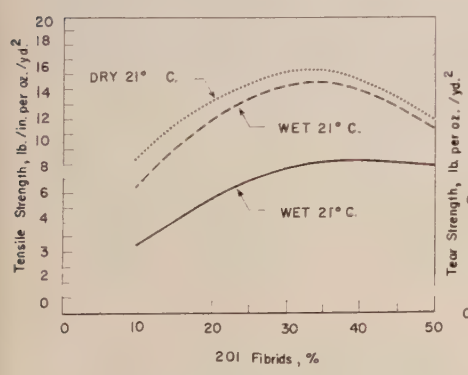


Fig. 3. Tensile strength vs. fibrid content

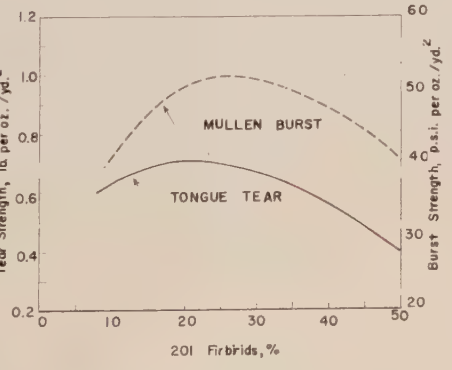


Fig. 4. Tear and burst strength vs. fibrid content

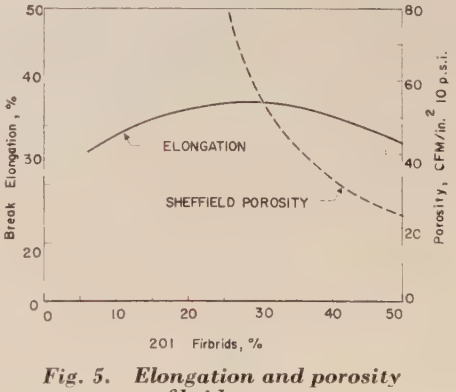
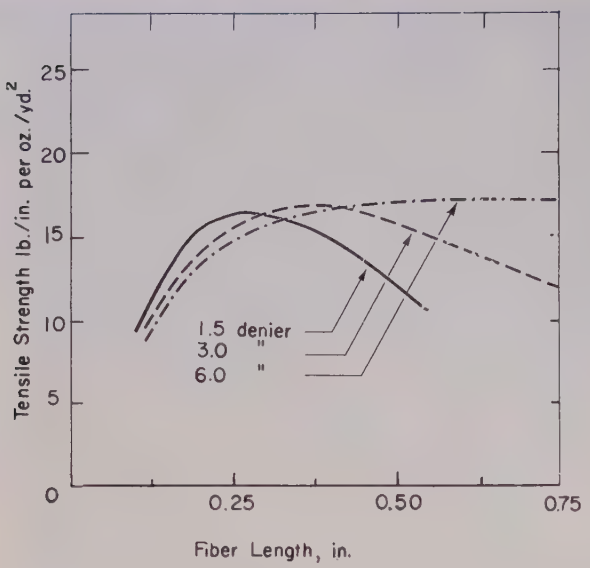
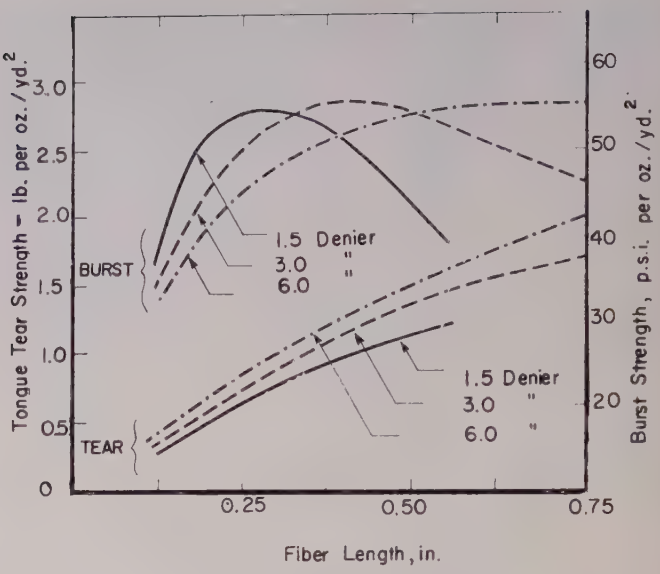


Fig. 5. Elongation and porosity vs. fibrid content

Fig. 3–5. Physical properties of textyls of Dacron





Figs. 6 and 7. Effect of fiber length and denier on tensile, tongue tear, and burst strengths, of textryls of Dacron

malized for basis weight. Tear, measured as tongue tear, is given in lb. per oz. per sq. yd. and Mullen burst in p.s.i. per oz. per sq. yd. As the fibrid content is increased, these properties also increase to a maximum and then fall off. However, the maximum is reached at somewhat lower fibrid contents than for maximum tensile strength—the peak is reached at a tongue tear strength of 0.7 lb. per oz. per sq. yd. with about 20% fibrid, and a Mullen burst of about 52 p.s.i. per oz. per sq. yd. at about 25% fibrid.

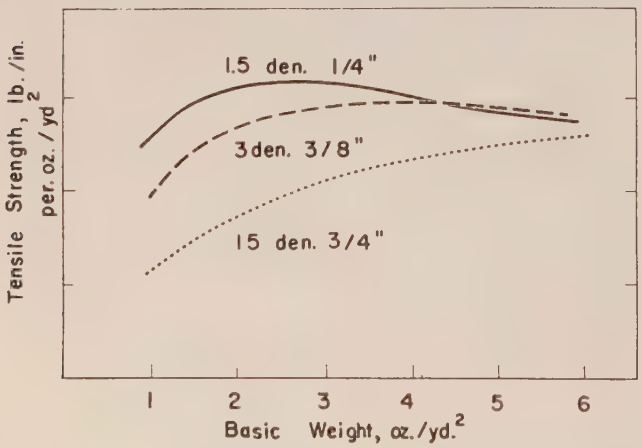
Figure 5 shows break elongation and porosity. The elongation curve also shows the characteristic maximum, reaching a value of about 33% at a fibrid content of 30%. High-strength calendered textryls are very porous, as shown by the Sheffield porosity measurements. However, at very high fibrid contents, the binder begins to form a more or less continuous phase, or film, and the porosity then drops to a very low level.

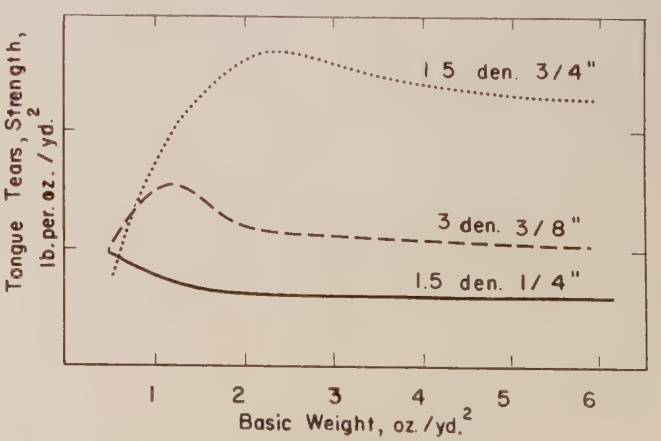
Effect of Fiber Morphology. Fiber diameter and length are other variables which are available for modifying textryl characteristics. Figure 6 shows the effect fiber length and diameter on textryl tensile strength at a constant fibrid content of 25%. Consider first the curve for 1.5-denier fiber. As the fiber length is increased, tensile strength reaches a maximum of 16 lb. per in. per oz. per sq. yd. at $^1/_4$ in. fiber length, and then falls off. If the fiber diameter is increased to 3.0 denier, the same maximum strength is reached but at $^3/_8$ in. fiber length, and the fall off is less rapid. With a 6.0-denier fiber, the maximum is very flat and is reached at about $^5/_8$ in. Two things can be observed from these data: (1) the maximum tensile strength is independent of fiber dimensions, and (2) the rate of decrease in strength with increased length is faster for the finer fibers. The second observation has been related to sheet formation, which deteriorates with very long fibers, and deteriorates more rapidly with the finer, and consequently more flexible fibers.

Figure 7 shows the relationship of burst and tear strength to fiber dimensions. Burst-strength behavior closely parallels tensile strength and needs no further comment. Tear strength behaves very differently with variation in fiber dimensions. Tear strength increases steadily with length over the length-range tested. Tear strength also increases with increasing fiber diameter at constant length.

Consideration of tensile and burst strength relationships shows that for maximum properties, there is an optimum length-to-diameter ratio. Taking into account data on a larger group of fibers, this ratio has been shown to be about 500. If is affected somewhat by fiber stiffness (modulus), being slightly lower for low-modulus fibers and slightly higher for those of higher modulus.

Basis weight has also been shown to have an effect on textryl properties. Figures 8 and 9 show the





Figs. 8 and 9. Tensile and tongue tear strength vs. basis weight, textryls of Dacron

Table I. Properties of Calendered Textryls

Fiber	Length in.	Denier	Fibrid, %	Tensile strength, lb./in./oz./yd.²	Elongation at break, %	Tongue tear, lb./oz./yd.²
Dacron polyester	1/4	3	25	15.2	33	0.7
Nylon polyamide	1/4	3	30	16.8	44	0.9
Orlon acrylic	1/4	3	30	8.0	13	0.3

relationship of tensile and tear strengths to basis weight for a variety of fiber dimensions. Strength falls off at low basis weights, and the lower the fiber diameter the lower is the minimum basis weight at which maximum strength can be reached. In tear strength, it will be seen that there is an optimum basis weight for maximum tear. The reason for this peak is not well understood but is believed to be related to the arrangement of the fibers in the direction normal to the plane of the sheet.

TEXTRYLS FROM NYLON AND ORLON ACRYLIC FIBER

Physical Properties

Similar data to the foregoing have been developed for textryls from nylon polyamide and Orlon acrylic fibers. Table I summarizes the properties of such textryls for a single composition, with the properties of a comparable textryl from Dacron polyester fibers given for comparison. Textryls of nylon are characterized by a very high combination of tensile strength and elongation, resulting in high work-to-break and toughness. Orlon acrylic fiber has lower properties than nylon or Dacron polyester, and this is reflected in lower physical properties in the textryl. However, Orlon acrylic fiber has outstanding resistance to degradation by light and chemical reagents, and this is reflected in the properties of the textryls from this fiber.

STRUCTURAL VARIATIONS POSSIBLE IN TEXTRYLS

The textryls discussed above have been hot calendered under conditions which fuse the fibrid binders and which develop the maximum strength properties. These calendered textryls are similar to conventional papers in being dense, smooth, and somewhat stiff. It is also possible to complete the bonding of the textryl by heat-fusing the fibrid binder in the absence of pressure. Under these conditions, a much more bulky, soft, and more drapeable sheet is obtained. The physical properties of such heat-fused textryls are lower than those of hot-calendered sheets, but are still at useful levels. Table II summarizes the properties of heat-fused textryls.

In addition to tailoring the structures by varying fiber dimensions, binder content and bonding conditions, many other finishing processes can also be used. Being thermoplastic, textryls are readily embossed to provide surface variation; by using multiple headboxes on the fourdrinier, layered structures can be produced; fibers and fibrids can be used as the furnish with shaped wires to produce formed articles. By such techniques, these new materials can be fabricated into structures with a wide range of properties.

MANUFACTURE OF TEXTRYLS

Stock Preparation

Synthetic papermaker's staple fibers can be readily dispersed in water with mild agitation at slurry consistencies of 0.05 to 0.1%. Fibrids are supplied as a damp cake of about 20% solids. They are dispersed in water in a hydrapulper at 1 to 3% consistency, and run through a Bauer disk mill to effect the final opening of the fibrous particles. Freeness can be reduced in this step, if desired, with closer settings of the disks. It is desirable to prepare fiber and fibrid stock separately and mix them just prior to feeding to the headbox to minimize fiber flocculation. Since the fibers are relatively long, high dilutions are used in the headbox, dilution water being added to the stock to give a consistency of about 0.025%. Figure 10 gives a flow diagram for one system which has been used.

Paper Machine

At these low consistencies, an inclined wire headbox on the fourdrinier has proved necessary to obtain good sheet formation. Figure 11 shows a satisfactory headbox. Other wet-end arrangements such as the Roto-Former can also be used. Conventional arrangements for removing the waterleaf from the wire are satisfactory. In the wet press, Teflon-coated press rolls prevent picking of the sheet. Drier can speed must be adjusted to conform to the shrinkage pattern of the synthetic sheet. Following the drier, the textryl can either be wound up for subsequent processing or run directly into a hot calender or fusing equipment to complete the bonding.

Calendering and Heat-Fusing

Calendering is carried out slightly above the fusing temperature of the fibrid, at about 400°F. for those fibrids which are currently available. Since the textryl must be raised uniformly to this temperature before it leaves the calender nip, preheating of the sheet is necessary to achieve commercial calendering speeds. Figure 12 shows the arrangement used in our laboratory. At low textryl basis weights, a single calender nip is sufficient. At higher basis weights two nips may be preferable. One calender roll in each pair is heated. A steel roll, heated electrically or by oil is used. The second roll is a resilient filled roll. The heated roll is coated with Teflon to prevent sticking of the textryl as it passes through the calender.

Heat-fusing without pressure requires that the

Table II. Physical Properties of Heat-Fused Textryls

Fiber	Length, in.	Denier	Fibrid, %	Tensile strength, lb./in./oz./yd.²	Elongation at break, %	Tongue tear, lb./oz./yd.²
Dacron polyester	1/4	3	25	8.9	28	0.7
Nylon polyamide	1/4	3	30	4.3	16	0.4
Orlon acrylic	1/4	3	40	5.1	5	0.3

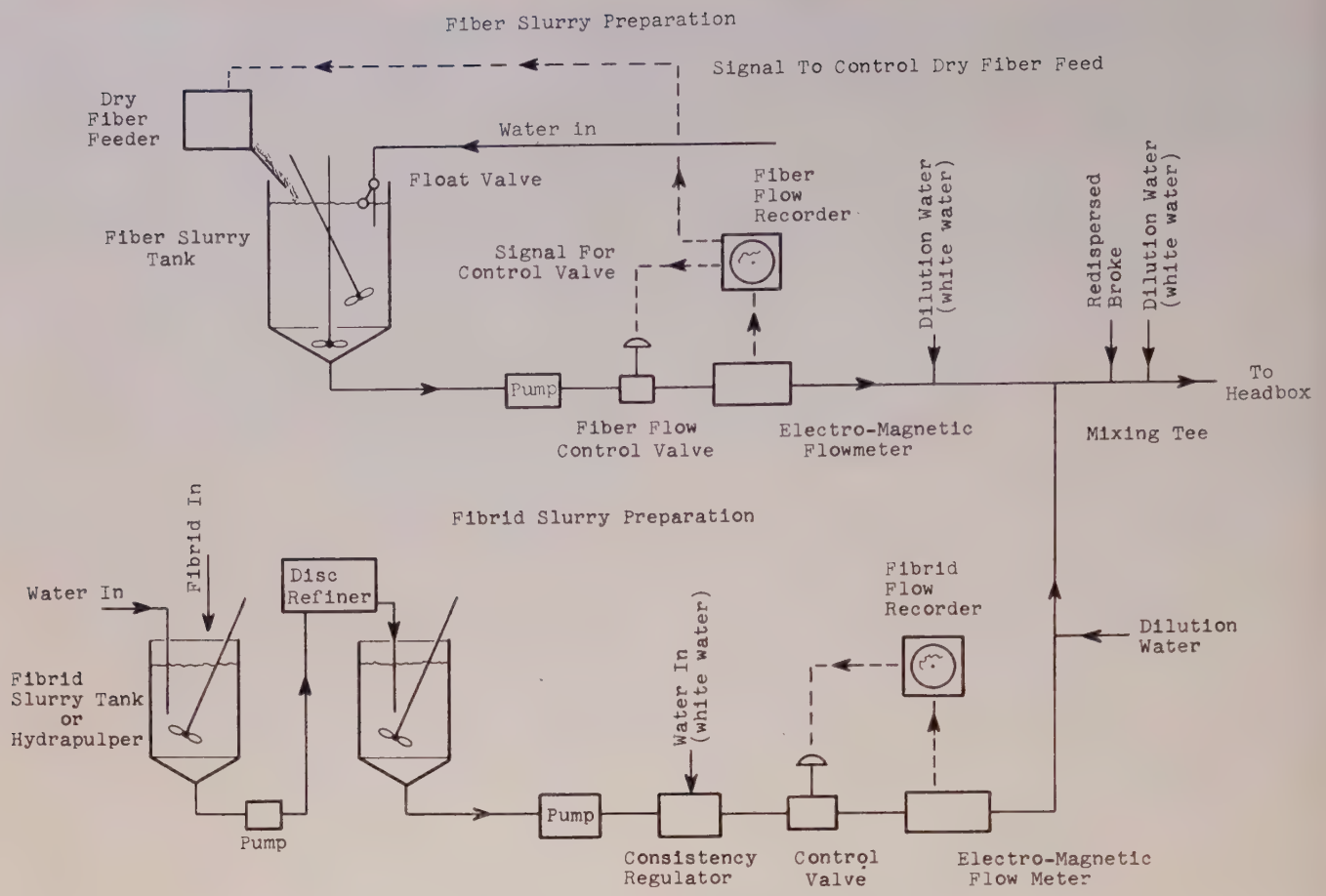


Fig. 10. Continuous stock preparation system

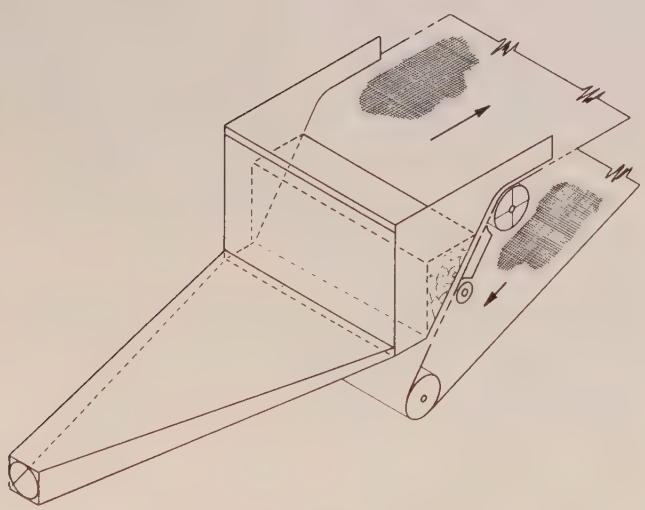


Fig. 11. Single layer headbox

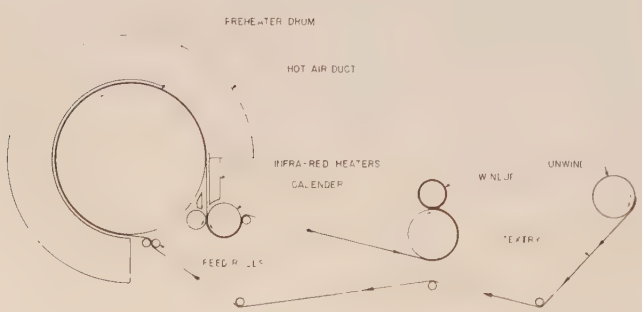


Fig. 12. Schematic diagram of high-speed textryl calender

textryl be raised to a temperature of about 430°F. for sufficient time to fuse the fibrids. The sheet requires some support, and provisions must be made for some shrinkage. This operation has been carried out on textile pin tenters and on the National Heat-Set Machine.* Other equipment designs for heat-fusing in line with the paper machine are obviously possible and details will depend on the particular machine arrangement.

CONCLUSIONS

Synthetic fibers provide a new group of raw materials for diversification of the paper industry. With fibrids as the binder, it becomes practical to handle these synthetic materials commercially on papermaking equipment, and to take full advantage of the inherent physical properties of the synthetic fibers.

By variations in the fibrids and fibers used, their distribution and amount in the sheet, and by the finishing processes which can be performed, a wide range of products can be tailored for various end-uses. These materials open up new opportunities for paper-machine products which, it is believed, will develop into a significant volume of business with time.

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* Product of National Drying Machinery Co., Philadelphia, Pa.

A Precision Method for the Analysis of Mixtures of Long and Short Fibered Pulps

F. P. HUGHES

A procedure has been developed for determining the proportions of hardwood and softwood in a mixture. The method is simple, fast, and accurate to 1% on unbeaten mixtures. Beaten pulps can be analyzed, with an accuracy which deteriorates slightly with lower freeness. The method consists in fractionating the pulp through a screen just big enough to pass the short fiber while retaining most of the long fiber. The retained fraction is weighed and the proportion of long fiber present is determined from a calibration graph.

THE increased use of hardwoods for pulp during the past decade or so has brought advantages, and problems to match. This paper is submitted as a practical solution to one of these problems—that of determining the composition of mixed pulps.

In many pulp mills, hardwood and softwood are produced serially, several days of hardwood production being followed by several days of softwood. Frequently some softwood pulp is produced with the hardwood and mixed with it, in order to simplify the screening. The hardwood pulp and the softwood pulp are stored and sold separately, though they are frequently blended to suit a given end use in the paper mill.

It is economically impossible to clean a pulp mill between the hardwood and softwood runs, so for many hours between runs the pulp produced is neither properly hardwood nor softwood. It is then known as "transition" pulp. Reference to Fig. 1 illustrates the matter. The limits of the graph are pure softwood (the upper) and pure hardwood (the lower). The horizontal axis represents time. Any vertical line crosses the plotted line at a point representing the pulp composition at that time. The shaded area designates hardwood.

At the beginning of this graph the (hypothetical) mill is producing softwood pulp—actually a mixture of 95% pine, say, and 5% poplar. During the second shift, the schedule calls for a change to hardwood pulp, so the type of pulp produced slowly changes from 95% softwood to 40% softwood. This cannot be sold or used as either major product, so it is labeled transition pulp and employed in furnishes where such pulp can be tolerated. Limits are set by management, and occasionally by governments, on the proportions of hardwood below which the pulp is considered softwood, and above which it is considered hardwood. The problem is, when are these limits reached? Obviously, an analysis is required.

The analysis should, ideally, have the following properties: (1) accuracy to 1%, (2) simplicity, (3) speed, (4) adaptability to automation, and (5) applicability to beaten pulps.

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The present TAPPI Standard (T 401 m-42) calls for a microscopic count of the fibers. This requires much continuous practice, is tedious, time consuming, and may be inaccurate. The standard itself claims an accuracy to 5%, but few will claim this accuracy under routine circumstances.

Other methods tried and found wanting when this problem came up at Marathon were The Institute of Paper Chemistry filtration resistance technique, which was too sensitive to slight changes in the pulps, and the standard four-screen classifier, the reasons for the abandonment of which must be considered in some detail.

If a pulp consisting of cellulose threads identical in length and diameter were available, these threads would, on fractionation, distribute themselves between the four screens, and the quantity of threads on a given screen would follow simple statistical laws. A mixture of these hypothetical threads with a batch similar in all respects except that of length, might possibly be sorted by the screens to give a meaningful pattern in the quantities of threads retained by the screens. Unfortunately, these perfectly regular pulps do not exist. Instead, we have a length distribution similar to Fig. 2.

In this graph the X axis represents length, and a histogram of the number of fibers between small limits of length is erected on it. In the limit, the histogram approaches the Gaussian distribution. If a large number of perfect screens were available, it would theoretically be possible to construct this histogram directly. However, the screens at our command are few and imperfect, retaining some fiber they should pass, and passing some fiber they should retain (see Table I). Each screen except the first retains its own fraction together with the errors of previous screens. It is easily seen that this method of sorting out becomes difficult.

The four-screen method of Hentola and Sihtola (*1*) relates the quantity of pulp retained on the two course screens mathematically with the quantity retained on the two fine screens and obtains the result by comparison with standard runs. Significantly, they make no claims for its accuracy.

It seemed, however, on grounds of accuracy and simplicity, that if the classification method was of any use at all, a single screen fractionation might serve. The immediate question became, of what mesh? The textbooks give the length of softwood fibers—e.g., southern pine—as 4 mm. and of hardwoods—e.g., poplar—as 1 mm. With this as a guide a 14 by 18-mesh screen was constructed. The results were most encouraging. After 20 min. fractionation over 70% of softwoods was retained; no hardwood tried gave a

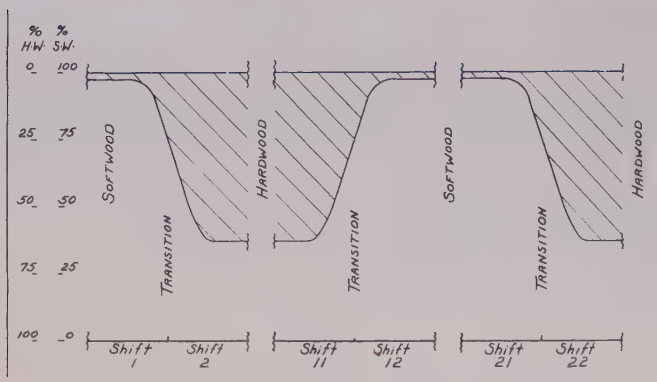

Fig. 1. Pulp production cycle

Shaded area represents hardwood.

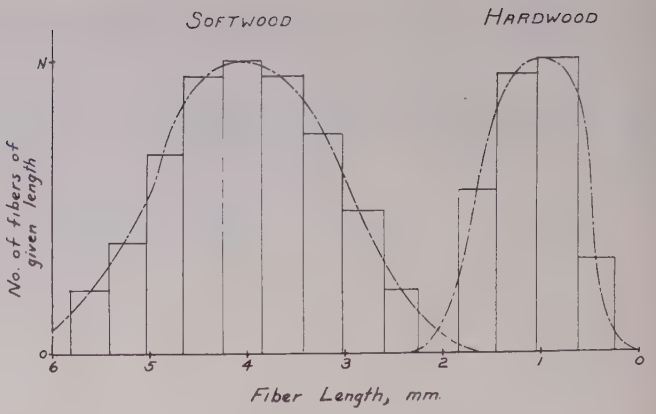

Fig. 2. Fiber length distribution

weighable fraction. This then, was a good starting place.

The method which evolved, which is outlined below, is readily learned and simple. It is also accurate to 1%, so it may possibly be considered an analytical method. Needless to say, since it is so precise, the test must be conducted with patience and care.

METHOD

Scope

This method is a means of determining the relative proportions of softwood and hardwood pulps in a mixture of the two.

Apparatus

1. A Bauer-McNett classifier, equipped with one, 14 × 18-mesh to the inch screen.
2. Stop clock.
3. Hotplate, controlled in temperature to 215–220°F.
4. Scale capable of weighing 15 g. with 0.01 g. accuracy.
5. Buchner funnel, filter papers, and vacuum pump.
6. Waring blendor.
7. Calibration graph, prepared from known mixtures of the pulps to be analyzed.

Procedure

Preparation of the Calibration Graph. Obtain pure samples of the pulps to be analyzed. Make mixtures of known quantities of the two pulps: 20, 50 and 100% softwood are suggested. Analyze by the procedure below. Prepare a graph of the amount of fiber retained against the quantity of softwood pulp in the mixture.

Sample Preparation. Take a sufficient amount of the sample to give approximately 12 g. oven dried pulp: Filter the pulp on a Buchner funnel. Dry the resulting pad. Weigh out 10 g. of the dry pulp, using adequate precautions to prevent moisture pickup, and slurry in approximately 700 ml. of water in a Waring Blendor.

Classification. Thoroughly clean the Bauer-McNett classifier. Insert a clean 14 × 18-mesh screen into a convenient tub. Set the water valve to give a moderate overflow through the overflow pipe. When all the tubs are filled, start the agitator.

Add the slurried sample to the tub with the screen, and start the stop clock simultaneously. Rinse the blender with water into the tub.

At approximately 19 min. and 50 sec. after the sample was added, turn off the water supply. At exactly 20 min. 0 sec. after the sample was added, turn off the agitator.

Allow the contents of the active tub to drain through a filter cloth. Wash the tub and screen thoroughly, running the wash water through the filter cloth.

Transfer the retained fiber from the filter cloth to the Buchner funnel, in which a tared filter paper has been placed. When filtration is complete, transfer the pad and the filter paper to the hotplate, dry, weigh to 0.01 g. From the weight of long fiber retained, read the proportions of long and short fibers from the calibration graph.

Report the average of two runs.

Alternate Procedure for Pulps Containing Little Long Fiber. If the pulp is known to contain only a small percentage of long fibered pulp, 8 g. of it are weighed out, and to this quantity 2 g. of known pure long fibered pulp of the same species as that being investi-

Table I

	Screen				
	I	*II*	*III*	*IV*	*Fines*
Retained on perfect screens	A	B	C	D	E
Fraction A is actually distributed:	a	b	c	d	e
Fraction B:	..	f	g	h	i
Fraction C:	..	..	j	k	l
Fraction D:	..	..	..	m	n

A = a + b + c + d + e, etc.

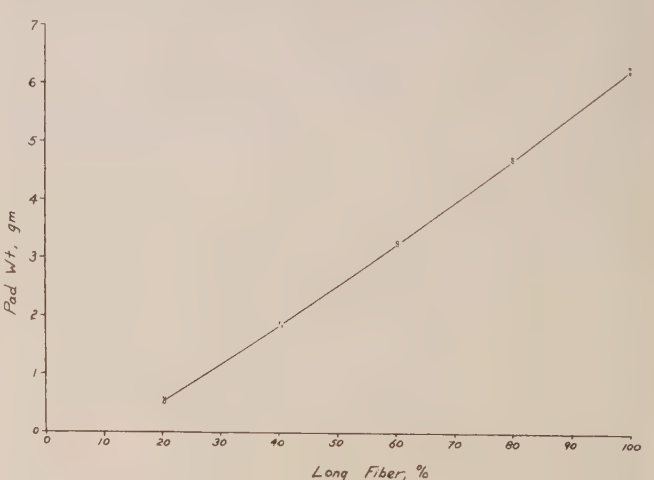

Fig. 3. Weights of fiber retained on screen from mixtures

Table II. Results of Determinations on Unknown Mixtures of Pine and Gum

Reference	Pine Found, %	Pine actual, %		Error
A	76.0	75.2	Operator I	+0.8
D	77.2	76.8		+0.4
E	79.0	77.5		+1.5
F	7.0	7.0		0
G	0.0	0.8		−0.8
H	0.5	0.5		0
I	24.2	25.0	Operator II	−0.8
J	28.0	28.0		0
K	40.0	40.0		0
L	24.1	24.0		+0.1
M	25.4	26.0		−0.6
N	25.0	25.0		0
O	93.5	94.0		−0.5
P	95.0	94.5		+0.5

gated is added. The procedure is then followed as above. Subtract 20 from the percentage of long fiber found. The result is the actual proportion of long fiber in the sample.

DISCUSSION

It will be noted that the procedure calls for weighing the oven-dried fiber, rather than suggesting the determination of the consistency and measuring out a given volume of the sample. This is because of the impracticability of obtaining the necessary accuracy by the volumetric method. In order to maintain the extreme accuracy of which the method is capable, 10 g. of the sample must be weighed to 10 mg. This is 1 part in 1000 a limit unattainable volumetrically with unbeaten long fibered stocks.

The first step in the development of this method was the analysis of a series of known mixtures of hardwood and softwood pulps. Where necessary, the pure pulps were obtained from basket or laboratory cooks. The results were plotted and are shown in Fig. 3. A straight line can be drawn through the plotted points of per cent softwood versus pad weight. Next, several unknowns were made up, and analyzed by the method. The results were most satisfactory except for those containing less than 20% pine for which a modification of the method had to be devised. This point represented development of a satisfactory analysis method for unbeaten mixtures. It was tested in two ways. First, two operators made a series of runs, each making his own calibration graph, and then analyzing a series of unknowns. The results were well within the required tolerance, as Table II shows. Then as many different pulps as possible were tried in the equipment. It had been thought that the change from one pulp to another would necessitate a different

Table III. Performance of Long Fibered Pulps Other Than Buckeye 287-60, Checked Against Buckeye 287-60 Calibration Curve

Reference	Pulp	Pine found, % 100% actual	Pine found, % 30% actual
287-275	East Texas via Oswego	99.9 98.5	30.0 29.5
287-260	East Texas via Rothschild	102 101	30 30
287-271	Crossett	96 97	28.5 27.5
287-270	Buckeye 270[a]	79 87.5	23 20

[a] Difficult to disintegrate, the pulp being very dry.

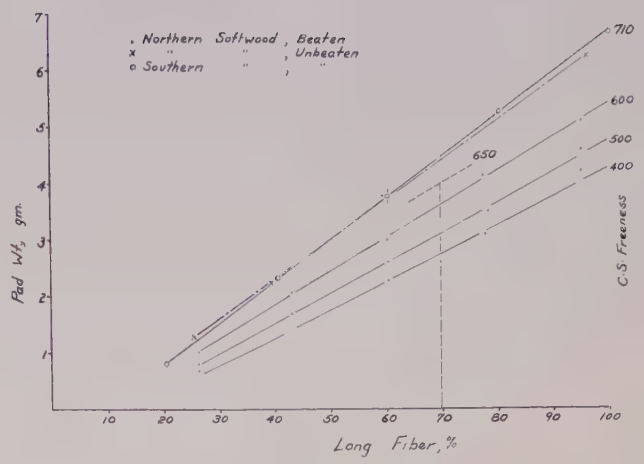

Fig. 4. Performance of beaten stocks

screen, but to our surprise the original screen worked for every pulp tried. Calibration was not correct, of course, but all hardwoods passed the screen completely, and 70% or so of all softwoods was retained (see Table III).

Lastly, the method was modified to allow the analysis of beaten pulp. A series of calibration runs was made as before, on known mixtures beaten to known freenesses. From these results, calibration curves at 600, 500, 400 C.S. freeness were established and used to check unknowns (see Fig. 4).

The use of the standard curves for beaten pulp is quite simple. The procedure outlined above is followed, and a freeness is taken on the sample. The intercept of the pad weight line and the line representing the freeness—which will usually have to be interpolated—is a point perpendicularly over the per cent long fiber in the mixture.

As a final check of the method, two technicians, familiar with the Bauer-McNett equipment but completely strange to the method, prepared a calibration graph at several freeness levels. Their only guidance was the standard method shown above. As Fig. 5 shows, their results are completely satisfactory.

It is found that operating the equipment manually involves a personal error in the results: Fig. 6 shows

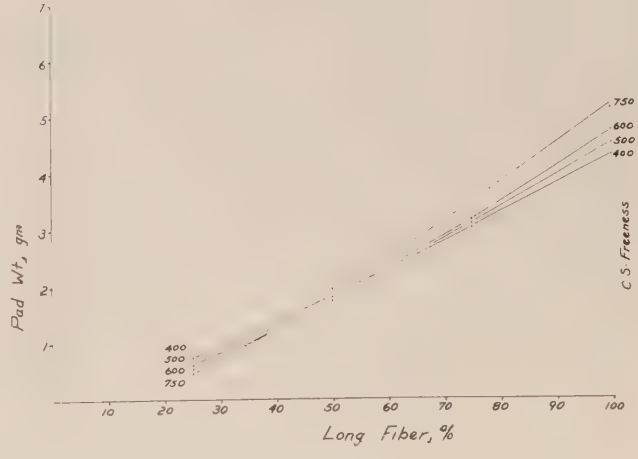

Fig. 5. Performance of beaten stock.
Southern kraft—av. of two operators.

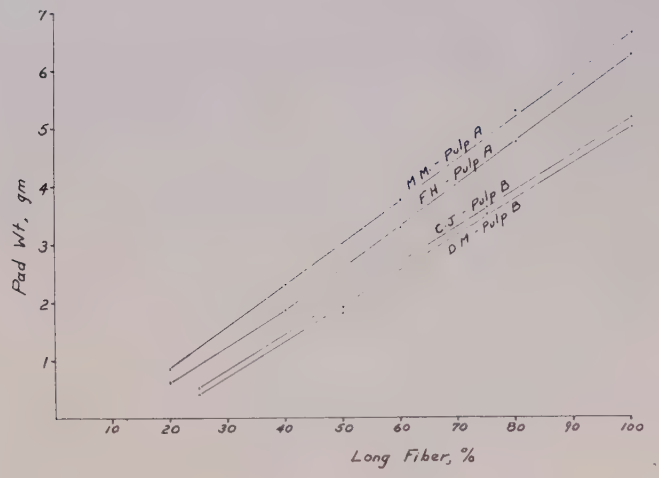

Fig. 6. Calibration curve comparison

that the calibration curves between operators differ perceptibly. So, to avoid the error which could be expected if every operator used the same curve, or the confusion of using a separate curve for each operator, it is recommended that the equipment be automated as far as possible.

CONCLUSION

This method enables a pulp mill to discover the composition of its pulp at any time, with satisfactory accuracy. Every attempt has been made to devise a practical routine test, and several short cuts are built into the method to expedite its performance. Its limitation is that the properties of the long fibered component must be known for the full accuracy of the method to be attained. This limitation is not of any great moment in the circumstances for which the test is designed.

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A C. J. West Memorial Award paper presented at the meeting of the Lake States Section of TAPPI, held in Menasha, Wis., May 12, 1959.

Studies on Lignin

XXXII. Ester Groups of Lignin

JUNZO NAKANO, ATSUSHI ISHIZU, and NOBUHIKO MIGITA

The distribution of *p*-hydroxybenzoate groups in the tree trunk and the site of ester linkage in lignin were studied on the aspenwoods *Populus nigra* Linn. and *Populus Maximowiczii* A. Henry, which contain large amounts of the *p*-hydroxybenzoate group. These amounts are approximately the same for samples obtained from the same height and same number of annual ring. The amounts of the *p*-hydroxybenzoate group are also approximately equal for both sapwood and heartwood, and also for each sample obtained from the same annual ring at various heights. From the results of periodate oxidation and hydrogenolysis of *P. Maximowiczii* "native lignin," it is concluded that at least a part of the *p*-hydroxybenzoate groups are located at the α-position of the lignin side-chain.

THE presence of ester groups in lignin was first demonstrated by Smith (*1*). *p*-Hydroxybenzoic, vanillic, syringic, *p*-coumaric, and ferulic acids were identified as the acidic components of these groups.

Previously (*2*), 19 species of various woods (four species of softwood, nine species of hardwood, and six species of tropical hardwood) were extracted with boiling 1 *N* sodium hydroxide solution, and the alkaline extracts were analyzed by paper chromatography to clarify the relationship between the species of wood and the types of ester groups present. The alkaline hydrolysis of hardwood has also been studied extensively by Pearl and co-workers for the same purpose (*3*, *4*).

The purpose of the present report is twofold: (1) to describe the distribution of *p*-hydroxybenzoate groups in the trunk of aspenwood, and (2), to explore the possibilities of determining the position of the ester linkage in the lignin molecule by means of periodate oxidation (*5*) and hydrogenolysis (*6*, *7*).

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EXPERIMENTAL

Analytical Determination

Two species of aspenwood were used as wood samples: *Populus nigra* Linn. and *Populus Maximowiczii* A. Henry. Representative, horizontally cut disks 1-in. thick were sampled from the upper, medium, and lower part of the tree trunk, and the selected annual ring was carefully separated and ground. Each woodmeal sample (40–80 mesh) was exhaustively extracted with ethyl alcohol–benzene 1:2. The extracted samples (150 mg.) were refluxed in 1 *N* sodium hydroxide solution (20 ml.) for 8 hr. The mixture was filtered through a sintered glass funnel, and the wood residue was washed twice with 8 ml. of 1 *N* sodium hydroxide solution. The original filtrate and washings were combined and acidified with glacial acetic acid to pH 4.4–4.6. The acidified filtrate was extracted with ether, the ether solution dried with anhydrous sodium sulfate and concentrated to a small volume. The residue was dissolved in a small amount of ethyl alcohol. *p*-Hydroxybenzoic acid was isolated by paper chromatography (developer: *n*-butyl alcohol saturated with water), and determined spectrophotometrically by the same method as described previously (*2*). Each woodmeal sample was determined in duplicate in a random order.

Periodate Oxidation

Periodate oxidation was carried out on *P. Maxi-*

Table I. Percentage Distribution of *p*-Hydroxybenzoic Acid on Different Sides of *Populus nigra* Linn. Height of Trunk, 13.18 m.; Annual Ring, 15

Sample	1	2	3	4
p-Hydroxybenzoic acid	1.3	1.4	1.3	1.3

Each sample number represents a sample taken from a different quadrant.

mowiczii "native lignin" (by the Brauns method) with and without treatment by 1 *N* sodium hydroxide solution for 8 hr. at room temperature. For comparison the amount of the α-glycol group of black spruce "native lignin" was also determined.

Lignin samples (0.5 g.) were sealed in a 100-ml. flask with 40 ml. of phosphate buffer solution (pH 5.9) and 10 ml. of 0.2 *N* sodium periodate solution. The flasks were shaken at room temperature (*ca.* 25°C.) for various periods of time (1, 5, and 8 hr.). Lead nitrate solution (12.5 g. per 100 ml., 20 ml.) was added to precipitate the iodate and periodate ions, and the solution was evaporated to dryness under reduced pressure in a stream of hydrogen gas. The distillate was treated with dimedone (dimethyldihydroresorcinol) in the usual way. The amounts of formaldehyde were calculated from the amounts of precipitate thus obtained.

Hydrogenolysis

P. Maximowiczii "native lignin" (150 mg.) was dissolved in 120 ml. of methanol (or dioxane), and shaken in a hydrogen atmosphere with 10% palladium-charcoal (150 mg.). At various intervals (5–15 hr.), the catalyst was removed by filtration, and the solution was evaporated to dryness under reduced pressure. The ether-soluble fraction of the residue was dried with anhydrous sodium sulfate, and examined by paper chromatography, as described previously. *p*-Hydroxybenzoic acid contents were determined spectrophotometrically by a method described earlier (*2*).

RESULTS AND DISCUSSION

Distribution of p-Hydroxybenzoate Groups in the Tree Trunk

Tree growth may be more rapid on one side of the trunk than on the other because of climatic conditions. It is, therefore, possible for a tree to be more or less lignified on one side than on the other, and it cannot be assumed that the distribution of the *p*-hydroxybenzoate groups is symmetrical about the longitudinal axis. It is important, therefore, for the preparation of wood-meal samples to determine whether or not the amounts of *p*-hydroxybenzoic acid are different according to the direction of growth in the trunk. The wood disk cut from the upper part of *P. nigra* (height of trunk 13.18 m., annual ring 15) was divided into four equal parts, and the amount of *p*-hydroxybenzoic acid was determined for each wood-meal samples

Table II. Percentage of *p*-Hydroxybenzoic Acid in Various Parts of *Populus nigra* Linn.

Height of trunk, m.	Annual ring 35	30	25	15	10
1.30	..	1.5	1.4	1.4	1.3
7.24	..	1.5	1.3	1.4	1.5
13.18	1.4	1.3	1.4	1.3	..

Table III. Percentage of *p*-Hydroxybenzoic Acid in Various Parts of *Populus Maximowiczii* A. Henry

Height of trunk, m.	Annual ring 40	35	30	25	18
1.30	1.4	1.6	1.3	1.5	1.3
8.42	1.5	1.4	1.5	1.4	..
15.54	1.5	1.5	1.3	1.4	..

(samples 1–4). Table I shows that the amount of *p*-hydroxybenzoic acid is approximately the same in each sample. When the distribution of *p*-hydroxybenzoate groups is examined, representative wood-meal samples can be obtained regardless of the direction of trunk growth if they are taken, at least, from the same height and the same annual ring.

The amounts of *p*-hydroxybenzoic acid in *P. nigra* and *P. Maximowiczii* are in the range of 1.3 to 1.5% and 1.3 to 1.6%, respectively, as shown in Tables II and III. It can be concluded that there is no difference in the amount of *p*-hydroxybenzoic acid with respect to the direction of the annual ring, and no difference in the samples taken from the same annual rings at various heights. That is to say, the amounts of *p*-hydroxybenzoate groups are approximately the same for both sapwood and heartwood, as reported recently by Pearl (*4*).

Sites of p-Hydroxybenzoate Groups in the Lignin Side-Chain

Smith (*1*) has concluded that the ester groups of lignin are located at the side-chain as shown in Fig. 1a. However, it is still unknown at what position of the side-chain the ester linkage is located. To clarify the location of the *p*-hydroxybenzoate group in the side-chain, periodate oxidation (*5*) and hydrogenolysis

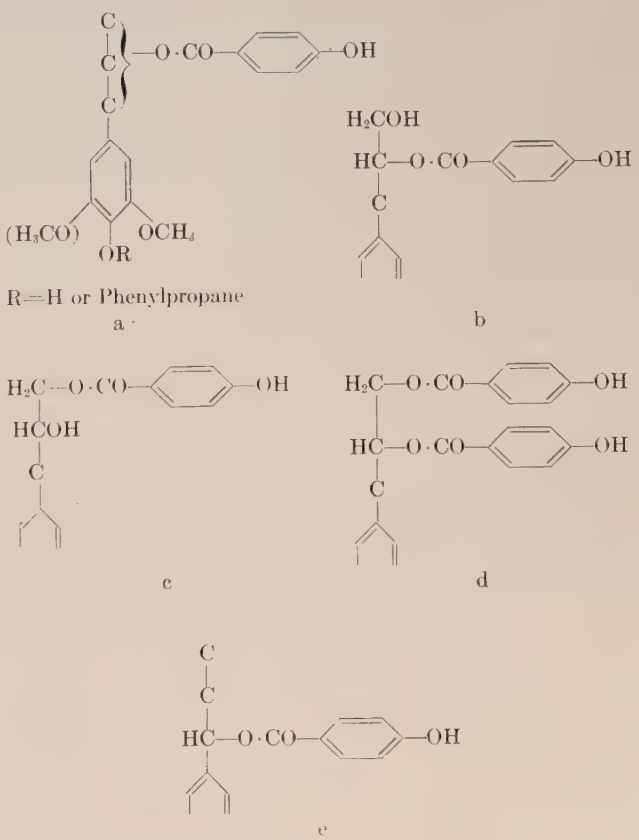

Fig. 1

Table IV. Periodate Oxidation of α-Glycol Groups in "Native Lignin"

Sample	Time, hr.	No. of α-glycol groups per 100 phenylpropane units[a]
Aspen "native lignin"	1.0	0.73
Aspen "native lignin" after 8 hr. in 1 *N* NaOH	1.0	0.85
Black spruce "native lignin"	1.0	0.80
Black spruce "native lignin" after 8 hr. in 1 *N* NaOH	1.0	0.90
Aspen "native lignin"	5.0	0.90
Aspen "native lignin" after 8 hr. in 1 *N* NaOH	5.0	1.00
Black spruce "native lignin"	5.0	1.18
Black spruce "native lignin" after 8 hr. in 1 *N* NaOH	5.0	1.24
Aspen "native lignin"	8.0	0.85
Aspen Aspen "native lignin" after 8 hr. in 1 *N* NaOH	8.0	0.98
Black spruce "native lignin"	8.0	1.02
Black spruce "native lignin" after 8 hr. in 1 *N* NaOH	8.0	1.20

[a] Molecular weight of phenylpropane unit taken as 200.

(*6*, *7*) were carried out on Brauns "native lignin" isolated from *P. Maximowiczii*. The yield of *p*-hydroxybenzoic acid from "native lignin" was 7.5%. This value corresponds to 1.6% of *p*-hydroxybenzoic acid based on wood meal (Klason lignin 21.4%), assuming all of the *p*-hydroxybenzoic acid to be combined with lignin.

The three types of ester linkages shown in Fig. 1b, 1c, and 1d represent the hypothetical side-chain structure that would form α-glycol groups in alkaline hydrolysis and produce formaldehyde in a subsequent periodate oxidation. Consequently, if such side-chain structures exist in lignin, the amount of formaldehyde produced by periodate oxidation should substantially increase after alkaline hydrolysis.

The results of the formaldehyde determinations are given in Table IV. A maximum value of the α-glycol group was obtained after oxidation for 5 hr. Comparing the amounts of α-glycol groups obtained at this stage, the difference between the lignin samples with and without the alkaline treatment is insignificantly small. Similar results were also obtained on black spruce "native lignin." Hence, no significant amounts of the above ester structures appear to exist in lignin.

In a previous publication (*7*), it was demonstrated that the ether or ester linkage at the α-position of the side-chain is quantitatively cleaved by the hydrogenolysis using 10% palladium charcoal, whereas the ether or ester linkage at the β-position remains unaffected by this treatment (some exceptions are known: Table V, taken from reference *7*). Based on this data, the hydrogenolysis of *P. Maximowczii* "native lignin" was carried out under various conditions in a standard apparatus. The release of *p*-hydroxybenzoic acid would indicate the α-position of the side-chain of lignin as its original site.

Table V. Hydrogenolysis of Model Compounds at Atmospheric Pressure

Sample	Sample weight, millimol.	Hydrogen absorbed, millimol. — Time of hydrogenolysis, min.	Calcd.	Found
Benzyl methyl ether	2.0	20	2.0	1.70
4-Methoxybenzyl-methyl ether	1.3	90	1.3	1.41
Vanillyl methyl ether	1.5	50	1.5	1.43
α-Phenylethyl alcohol	1.6	26	1.6	1.61
α-Phenylethyl acetate	1.8	90	1.8	1.68
β-Phenylethyl acetate	1.8	90	..	No uptake
Methyl-α-phenylethyl ether	1.8	35	1.8	1.64
Methyl-β-phenylethyl ether	2.2	90	..	No uptake
Ethyl-α-phenylethyl ether	1.4	35	1.4	1.34
Ethyl-β-phenylethyl ether	1.8	90	..	No uptake
4-Methoxy-ethyl-α-phenylethyl ether	1.8	100	1.8	1.62
Veratryl guaiacyl ether	0.8	130	0.8	0.82
Dibenzyl ether	1.5	35	3.0	2.82
Dehydrodihydrodiiso-eugenol	0.8	90	..	No uptake
Dehydrodihydrodiiso-eugenol methyl ether	0.5	90	..	No uptake

Table VI. Hydrogenolysis of *Populus Maximowiczii* "Native Lignin" (10% Pd-C)

Hydrogenolysis conditions — Solvent	Pressure	Time, hr.	Temp., °C.	p-Hydroxybenzoic acid, % Based on "native lignin"	Based on p-hydroxybenzoic acid[a]
Methanol	Atmospheric	8.0	45	0.09	1.2
Dioxane	Atmospheric	5.0	75	0.08	1.1
Dioxane	Atmospheric	8.0	75	0.16	2.1
Methanol	3 kg./cm.²	5.0	Ambient	0.08	1.1
Methanol	3 kg./cm.²	8.0	Ambient	0.09	1.2
Methanol	3 kg./cm.²	15.0	Ambient	0.14	1.9

[a] Based on 7.5% of *p*-hydroxybenzoic acid in *P. Maximowiczii*. "native lignin."

Table VI shows that a very small amount of *p*-hydroxybenzoic acid was obtained in the hydrogenolysis. This was not detected in the blank test under similar conditions in which hydrogen gas was not used. Therefore, it can be concluded that at least part of the *p*-hydroxybenzoate groups are located at the α-position in the side-chain (Fig. 1e). Hydrogenolysis of the benzyl ether and ester group appears to be difficult due to the nature of the ether and ester, and by the steric hindrance of the ether or ester itself or neighboring groups (*7*). Considering such a hindrance for hydrogenolysis, it would be expected that more than those amounts of *p*-hydroxybenzoic acid found are located at the α-position of the lignin side-chain.

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Dirt Contribution Values for Natural Dirt in Coniferous Woods

Balsam, Alpine Fir, and Black Spruce

DAVID IRWIN and B. E. LAUER

The contribution of natural dirt in pulpwood chips to the occurrence of dark specks in both bleached and unbleached pulp has been determined for samples of balsam, alpine fir, and black spruce. The samples were cooked by acid sulfite cooking procedures. Results obtained checked, in general, with those reported for samples of dirt from Engleman spruce and hemlock. As with these two species, the outer bark was found to be a much larger contributor of specks in the pulp than was any other type of dirt. The inner bark and knots of every type were also major contributors of dark specks in pulp. Determinations indicate that results reproducible within ±25% should be possible with the method of examination used.

THE experimental work described in this paper was performed essentially for the purpose of developing experimental data concerning the amount of dirt introduced into pulp by natural dirt in pulpwood chips. These data, together with those reported earlier (*4*), were to be used as a basis for a revision of TAPPI Standard Method T 14 m-47. Alpine fir, balsam, and black spruce were the species studied. The cooking was done in an acid sulfite medium.

PROCEDURE

Procedures for sorting the chips, preparation and treatment of the pulp, and estimating the dirt in the pulp sheets were essentially identical to those used previously and described in detail by Rowland (*2*). In brief the procedure was as follows.

Sorting

A 12-lb. sample of each species of chips was obtained for examination. The sample was first screened on a 3-mesh standard screen to remove fines. The fines which were removed were weighed for record. The chips were then sorted into two classes, dirty and clean, and the dirty chips sorted into as many of the 15 types of dirt described by Santos (*3*) and Rowland (*2*) as were present. Each sample was immediately weighed after sorting. The aggregate weight after sorting was used as a basis for calculation of percentages of each dirt type in the gross sample. No adjustment was made for change in moisture content in that it was felt that the moisture content of all samples would change in similar amounts, and that the precision of the overall procedure was not one which could justify this step.

Cooking

Pyrex glass tubes, 1-in. inside diameter and 23 in. long, were partially filled with chips containing a single dirt type. Sulfite cooking liquor was then added in sufficient quantity to cover the chips in the tubes. The tubes were promptly sealed and allowed to stand overnight. They were then inserted in a metal holder and the tube and holder assembly placed in a rocking autoclave. The autoclave was partially filled with water and sealed. The temperature was raised to 100°C. in 1 hr. and then slowly increased over a 2-hr. period to a maximum temperature which depended on the species of wood being cooked. The cook was continued for $3^1/_2$ hr. at the maximum temperature to give a total of $6^1/_2$ hr. for the cook. The maximum temperature found most suitable for balsam was 140°C., for alpine fir, 139°C., and for black spruce, 144°C.

At the end of the cooking period the pressure in the autoclave was released and the autoclave promptly opened. The tubes were immediately removed and quickly cooled to room temperature. The tubes were then broken and the cooked chips transferred to a Buchner funnel where they were thoroughly washed with hot water.

Treatment of the Pulp

The washed chips were pulped for 20 min. in an ordinary, intermeshing blade, kitchen mixer. The resultant pulp sample was screened through a screenplate having slots 0.01 in. in width. The screened sample was divided into approximately equal parts. One of the two parts was bleached by treatment with calcium hypochlorite solution for about 5 hr. The pulps, unbleached and bleached, were then made into handsheets weighing approximately 0.01 g. per sq. in. All parts of the screen frame and sheet mold (except the screen surfaces) were constructed of plastic so as to avoid the introduction of dirt into the pulp from mechanical sources.

Dirt Determination

The equivalent black area of the pulp sheets (dirt) was determined by a procedure which varied only in minor detail from that described in TAPPI Standard Method T 213 m-43. The airdry sheets were weighed and the dirt count results were recorded as square millimeters of equivalent black area per gram of pulp.

RESULTS AND CONCLUSIONS

Chip Sorting Results

Table I shows the distribution of the dirt-containing chips in the three species studied.

Dirt Contribution Determinations

Table II shows the contribution of the several kinds

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Table I. Percentage Composition by Weight of Chip Sample by Dirt Type

Weight of Sample before Screening, 12 lb.

Dirt type	*Sample I, balsam*	*Sample II, alpine fir*	*Sample III, black spruce*
Clean	64.1	79.3	76.6
Outer bark	0.0	0.8	0.0
Inner bark	4.1	2.8	0.7
Brown stain	17.3	8.1	4.5
Grey stain	5.4	0.8	4.3
Dark knots	1.0	1.2	1.8
Dark hard knots	1.4	0.4	0.0
Light knots	1.7	3.6	4.4
Light hard knots	1.5	0.4	0.7
Pin knots	1.2	1.2	4.8
Brown rot	0.3	0.0	0.0
White rot	0.0	0.1	0.1
Insect holes	1.0	0.2	0.0
Resin pockets	0.7	0.9	0.7
Black streak	0.0	0.0	0.0
Pith	0.3	0.2	1.4
Total, %	100.0	100.0	100.0
Minus 3-mesh fines, as a percentage of the original sample before sorting	12.7	11.9	14.0

of dirt to the dirt-speck count of the pulps produced from the dirt-containing chips. Some observations concerning the dirt contribution values reported in Table II are as follows.

Although it appears that outer bark is seldom encountered in pulpwood chips, it would, if present, contribute dirt to the pulp in excessive amounts.

The pulp made from the alpine fir chips containing outer bark yielded bleached sheets which had roughly one-half of the dirt count of the unbleached sheets. However, the sheets, both bleached and unbleached, made from the pulp which contained outer bark as a dirt contributor were much darker overall in color than those made from chips containing any other dirt type. Color appeared to be transferred from the bark to the otherwise clean pulp during the cooking process.

Bleaching, in general, greatly reduced the dirt count of the pulp. There were several exceptions to this generalization. For example:

a. The dirt contributed by the dark knots and dark hard knots was apparently little affected by the standard bleaching procedure.

b. The pulp made from some samples of light knots and light hard knots also yielded dirts which appeared to resist bleaching.

Table III. Check on Reproducibility of Results of Dirt Contribution Estimation Procedure

Results expressed as square millimeters of equivalent black area per gram of pulp

Dirt type	*Determination 1*	*Determination 2*	*Determination 3*
Engleman Spruce[a]			
Dark knots			
Unbleached	41.0	25.6	27.1
Bleached	19.8	12.5	7.2
Brown stain			
Unbleached	35.3	37.8	31.1
Bleached	2.1	8.2	1.5
Pin knots			
Unbleached	24.1	24.1	..
Bleached	9.2	14.8	..
Balsam			
Clean chips			
Unbleached	2.7	3.3	3.0
Bleached	2.0	2.0	1.5
Gray stain			
Unbleached	10.3	8.8	..
Alpine Fir			
Clean chips			
Unbleached	4.4	3.8	3.5
Bleached	2.8	2.8	2.4
Black Spruce			
Clean chips			
Unbleached	1.1	1.3	..
Bleached	0.2	0.1	..
Pin knots			
Unbleached	19.7	12.2	15.4
Bleached	12.1	9.2	8.3
Brown stain			
Unbleached	29.9	27.0	30.5
Bleached	10.2	10.4	11.3

[a] Rowland (*2*).

c. In a few cases pulp sheets made from a sample containing the dirt from knots gave a higher dirt count when bleached than when unbleached. The reason for this may be that the bleach improves the color of the background without affecting the dirt specks, thereby heightening the contrast and giving the appearance of more dirt in the pulp. This situation was encountered and discussed by both Santos (*3*) and Birkhimer (*1*).

Comparative Values

As a test of the overall reliability of the dirt estimation procedures several duplicate determinations were carried out. Table III gives the data reported by Rowland (*2*) together with those collected in this work.

It would appear from these data that in general, duplication within ±25% of a mean value is possible. Only a very few results have fallen outside that range, and these have been in the low areas where small actual

Table II. Dirt Count Contribution Values for Dirt in Pulpwood Chips

Dirt type	*Dirt count of pulp sheets, sq. mm. black area per g. pulp*					
	Balsam		*Alpine fir*		*Black spruce*	
	Unbleached	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*
Clean	3.0	1.8	3.9	2.7	1.2	0.2
Outer bark	..	..	2040	950	..	..
Inner bark	9.3	4.8	32.4	9.7	27.7	2.9
Brown stain	3.8	2.2	24.6	12.8	29.1	10.6
Grey stain	9.5	1.6	36.3	4.6	4.7	0.8
Dark knots	24.0	27.0	63.6	60.2	83.0	84.6
Dark hard knots	25.2	15.4	72.0	76.0	..	..
Light knots	20.5	4.0	35.0	8.6	22.0	23.7
Light hard knots	4.0	2.0	37.6	8.0	20.8	18.7
Pin knots	46.1	15.0	21.5	10.5	15.8	9.9
Brown rot	6.6	2.8	..	..	..	..
White rot	..	..	4.1	4.1	2.2	0.8
Insect holes	3.8	1.8	3.8	3.2	..	..
Resin pockets	13.1	2.8	35.3	20.3	17.3	2.4
Black streak	..	..	..	..	..	..
Pith	12.9	6.7	20.0	7.0	7.2	3.5

differences are reflected in large percentage variations. It should be safe to assume, therefore, that the values reported in Table I, as well as those reported by Birkhimer (*1*) and Rowland (*2*) for contribution to the speck content of pulp made from dirty chips, are also within that range of accuracy. With the necessity for individual judgment on at least two points in the overall procedures together with the gross variations possible within the character of the dirt itself, its actual proportion of the chip, and finally on one or more of the steps in the pulp preparation, a variation within ±25%, as wide as it is, should be considered thoroughly acceptable.

RECOMMENDATION

The results obtained in the experimental work reported in this paper, together with those reported earlier in this general study (*4*) suggest the desirability of a change in TAPPI Standard Method T 213 m-43.

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Studies on the Mechanism of Wet Strength Development. Part III

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The temperature dependence of the rate of development of wet strength in papers, treated with a commercial cationic urea formaldehyde resin, has been measured. Measurements were made with a number of different freenesses, pH and resin concentrations. The earlier conclusions that the pulp is not involved in the curing process was confirmed. Some other general observations on the mechanism of wet strength are also presented with reference to pH dependence and stress—strain data.

In Part I of this series (*1*) it was shown that the overall activation energy associated with the development of wet strength was similar for papers from cotton, unbleached kraft, and glass fibers treated with a simple unmodified urea-formaldehyde resin. This result was interpreted as giving a strong indication that the mechanism of cure of wet-strength resins of this type was independent of the nature of the fiber and consisted only of the second stage cross-linking reaction of the resin itself. However, such results would not rule out reactions between the fiber and the resin if these had similar activation energies. It was thought of interest, therefore, to extend this approach to a commercial, fast curing urea-formaldehyde resin and also to examine the effects of pH, pulp freeness, and the method of resin addition on the temperature dependence of cure.

EXPERIMENTAL

The glass fiber, kraft saturating, and filter papers used had similar origins and characteristics to those given in Part I (*1*). The handsheets used were prepared from pulp having the properties given in Table I. Appropriate amounts of resin and pulp were combined for the beater addition experiments, mixed for 15 min., and the pH adjusted to either 3.0 or 5.0 with a concentrated solution of alum and mineral acid. The handsheets were formed in accordance with TAPPI Standard T 205 m-55 in a British standard sheet mold with a white water recirculating system. The first ten handsheets from each run were discarded in order to establish equilibrium in the white water.

The saturation experiments utilizing mill-made papers and the testing procedures were as previously described (*1*). The initial rates of wet-strength development were calculated by the same tangent method used in the earlier work. With this resin, however, there was found to be a measurable degree of wet strength following drying at room temperature and the standard 24-hr. conditioning period. Consequently, the tangent was taken from the point of original wet strength and not the origin. This initial wet strength was probably due to a degree of resin advancement in the treated samples. Temperatures of 90, 105, 120, and 140°C. were used to determine the temperature-dependence values.

The resin used throughout this study was a commercial cationic modified urea-formaldehyde resin, Uformite 711 (Rohm and Haas Co., Philadelphia, Pa.). It was supplied as a solution of 35% solids content, a pH of about 8.0, and was infinitely dilutable in water.

RESULTS AND DISCUSSION

Thirty-seven separate experiments were conducted and all the activation energies obtained are presented together in Table II. These values were determined on the basis of the Arrhenius equation, which relates the rate of reaction of a process requiring activation and the temperature. The mean activation energy was calculated to be 12.2 kcal. per mole for all the cellulosic fiber papers. Statistically, the calculated values lie on the interval 12.2 ± 0.8 kcal. per mole 99% of the

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Table I. Pulps Used

Type → / *Origin →*	*Unbleached kraft Softwood, Enzo Gutzeit, Finland*	*Bleached sulfite Raybond P, Rayonier, Inc.*
Lignin, %	1.6	...
Pentosans, %	10.1	...
Alpha-cellulose, %	78.9	88.5
Benzene–ethanol extract, %	...	0.23
Ash, %	0.91	0.12
Nitrogen, %	0.38	0.41

time. The two glass-paper values of 12.3 and 12.7 kcal. per mole are well within these limits. It would appear then, that if there is a difference in the activation energy due to any of the variables studied, it is not statistically important. The above results completely confirm the results obtained earlier with the unmodified urea-formaldehyde resin; i.e., that the primary reaction in curing is the polycondensation of the resin into a cross-linked structure. The lower activation energy indicates the relative ease of curing of the modified resin, and brings the temperature dependence of cure for the modified urea resin into the same range as that for melamine resins (*2*), 11.0 kcal. per mole. A number of other measurements were carried out although maximum wet- and dry-strength measurements were not as reproducible and consistent as the actual rates of wet-strength development.

Table II. Summary of Overall Activation Energies Obtained

Pulp	*C.S. freeness, ml.*	*pH*[a]	*Method of addn.*	*Resin content, %*	*Activation energy, kcal./mole*
Unbleached kraft	211	3.0	Beater addn.	0.46	11.8
"	"	"	" "	1.54	12.5
"	"	"	" "	2.94	12.1
"	"	"	Saturation	0.77	11.5
"	"	"	"	5.63	12.1
"	"	5.0	Beater addn.	0.33	11.5
"	"	"	" "	1.50	11.7
"	"	"	" "	2.97	12.7
"	"	"	Saturation	0.67	12.5
"	"	"	"	5.53	12.4
"	536	"	Beater addn.	0.58	12.4
"	"	"	" "	1.54	13.5
"	753	3.0	" "	0.32	11.2
"	"	"	" "	1.09	11.5
"	"	"	" "	2.21	12.9
"	"	"	Saturation	0.58	12.4
"	"	"	" "	6.04	11.8
"	"	5.0	Beater addn.	1.01	11.8
"	"	"	" "	2.39	11.2
"	"	"	Saturation	0.61	10.9
"	"	"	" "	4.94	11.4
Bleached sulfite	232	3.0	Beater addn.	0.51	12.1
"	"	5.0	" "	0.88	12.9
"	705	3.0	" "	0.53	12.6
"	"	5.0	" "	0.78	13.4
"	232	3.0	Saturation	3.65	12.1
"	"	5.0	"	3.55	13.2
"	705	3.0	"	4.62	12.1
"	"	5.0	"	4.40	12.4
Filter[b] paper	..	5.0	"	1.50	12.8
"	..	"	"	2.90	12.6
"	..	"	"	5.18	12.3
Glass-fiber Paper[b]	..	"	"	1.52	12.3
"	..	"	"	5.31	12.7
Unbleached[b] kraft "Nibrocel"	..	"	"	0.95	11.6
"	..	"	"	3.29	13.3
"	..	"	"	5.07	12.5

[a] The pH is that of the saturating bath (and of sheet formation in the case of handsheets).
[b] Mill-made papers.

Table III. Effect of pH of Formation and Saturation on Wet Strength of Handsheets
Resin Content, 0.6%

Temperature, °C.	*Minutes*	*Wet tensile strength, kg./15 mm. Paper formed at pH 3.0, saturated at pH 5.0*	*Paper formed at pH 5.0, saturated at pH 3.0*
	0	0.49	0.32
90	8	0.89	0.62
	24	0.96	0.64
	60	1.36	0.78
140	1	0.79	0.45
	2	1.03	0.81
	4	1.75	1.06
	8	1.40	1.00

Both the beater addition and saturation studies on unbleached kraft and bleached sulfite handsheets showed the expected dependency of the rate of wet strength development on the hydrogen ion concentration. At the lower pH the rate of cure is greater regardless of the type of pulp, method of addition, or the freeness. An increase in the rate of wet-strength development at any given pH could be effected by additional refining of the stock before resin treatment, an increase in resin content, or an increase in the curing temperature. In most saturation experiments the handsheets used were formed at the same pH at which they were saturated; however, in one case the sheets were formed at a pH of 3.0 and saturated at pH 5.0, and in another experiment the pH sequence was reversed. The results are summarized in Table III where it appears that in handsheet experiments of this kind it is the pH at which the paper is formed that governs the rate of wet-strength development. Apparently the actual pH of the saturated paper is the same as at sheet formation. Presumably longer saturating times would bring the pH of the paper closer to that of the saturating bath.

A number of maximum wet-strength values for both

Table IV. Maximum Wet Strengths Obtained with Handsheets for Various Conditions of Treatment

Paper	*Made of resin addition*	*pH*	*Resin content, %*	*Maximum wet strength, kg./15 mm. 90°C.*	*140°C.*
Unbleached kraft 211 ml. C.S. freeness	Saturation	3.0	0.77	1.15	2.17
"	"	5.0	0.67	0.81	1.47
"	"	3.0	5.63	3.81	4.64
"	"	5.0	5.53	1.73	4.17
"	Beater addn.	3.0	0.46	0.90	1.78
"	" "	5.0	0.33	0.56	0.91
"	" "	3.0	2.94	2.50	2.84
"	" "	5.0	2.97	1.51	3.20
753 ml. C.S. freeness	Saturation	3.0	6.04	2.33	2.63
"	"	5.0	4.94	1.38	1.83
"	Beater addn.	3.0	0.32	0.77	1.17
"	" "	5.0	0.50	0.44	0.60
"	" "	3.0	2.21	1.86	2.39
"	" "	5.0	2.39	1.54	2.50
Bleached sulfite 232 ml. C.S. freeness	Saturation	3.0	3.65	2.32	2.56
"	"	5.0	3.55	1.04	2.18
"	Beater addn.	3.0	0.51	1.48	2.0
"	" "	5.0	0.88	0.68	1.54
705 ml. C.S. freeness	Saturation	3.0	4.65	0.96	2.14
"	"	5.0	4.40	0.51	1.20
"	Beater addn.	3.0	0.53	0.70	0.92
"	" "	5.0	0.78	0.69	0.94

Both the beater addition and saturation studies on unbleached kraft and bleached sulfite handsheets showed the expected dependency of the rate of wet strength development on the hydrogen ion concentration. At the lower pH the rate of cure is greater regardless of the type of pulp, method of addition, or the freeness. An increase in the rate of wet-strength development at any given pH could be effected by additional refining of the stock before resin treatment, an increase in resin content, or an increase in the curing temperature. In most saturation experiments the handsheets used were formed at the same pH at which they were saturated; however, in one case the sheets were formed at a pH of 3.0 and saturated at pH 5.0, and in another experiment the pH sequence was reversed. The results are summarized in Table III where it appears that in handsheet experiments of this kind it is the pH at which the paper is formed that governs the rate of wet-strength development. Apparently the actual pH of the saturated paper is the same as at sheet formation. Presumably longer saturating times would bring the pH of the paper closer to that of the saturating bath.

A number of maximum wet-strength values for both

beater addition and saturation procedures on handsheets are given in Table IV. Maximum values for wet strength were found to be much less consistent with any given pattern of behavior than rates, although they were reproducible. However, in addition to the faster rate of cure at the lower pH it was clear that the maximum value at pH 3.0 is much higher than at pH 5.0 for the 90°C. cure. There appears to be a tendency for the wet-strength values to be closer to-

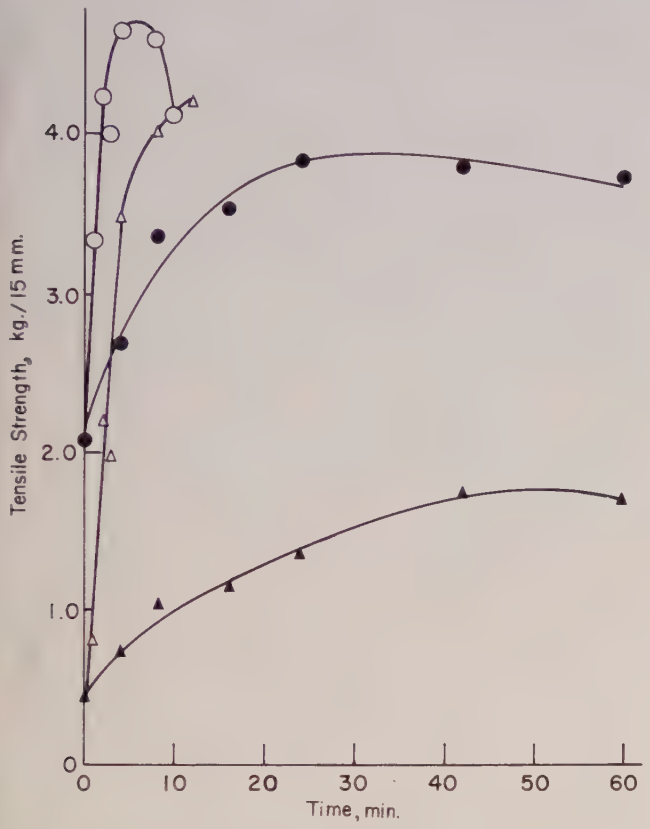

Fig. 1. The effect of temperature on the wet strength of unbleached kraft. 5.55% resin; saturated handsheets

○ 140°C., pH 3.0. △ 140°C., pH 5.0. ● 90°C., pH 3.0. ▲ 90°C., pH 5.0.

gether at the 140°C. The wet strength as a function of time for such an example is presented in Fig. 1. It would seem that a fast rate of cure at elevated temperatures is preferable for developing optimum wet strength and similar effects were also shown by using radiant heat for short intervals (*3*). The reason for this is not clear but it could be due to the cure being accompanied by less degradation at higher temperatures and shorter times, the lower equilibrium moisture content at higher temperatures undoubtedly could retard the reverse hydrolysis process (*4*).

The effect of the amount of resin is to give increasingly greater wet-strength values for all kinds of pulp and at all freeness levels. The wet-elongation figures are also steadily increased and both effects are best illustrated by the family of wet and dry stress–strain curves presented in Fig. 2. The dry tensile, elongation, and modulus can be seen to increase much less than the wet values and this can be taken as an indication that the function of the resin is to protect and waterproof the existing bonds as well as to form additional water-

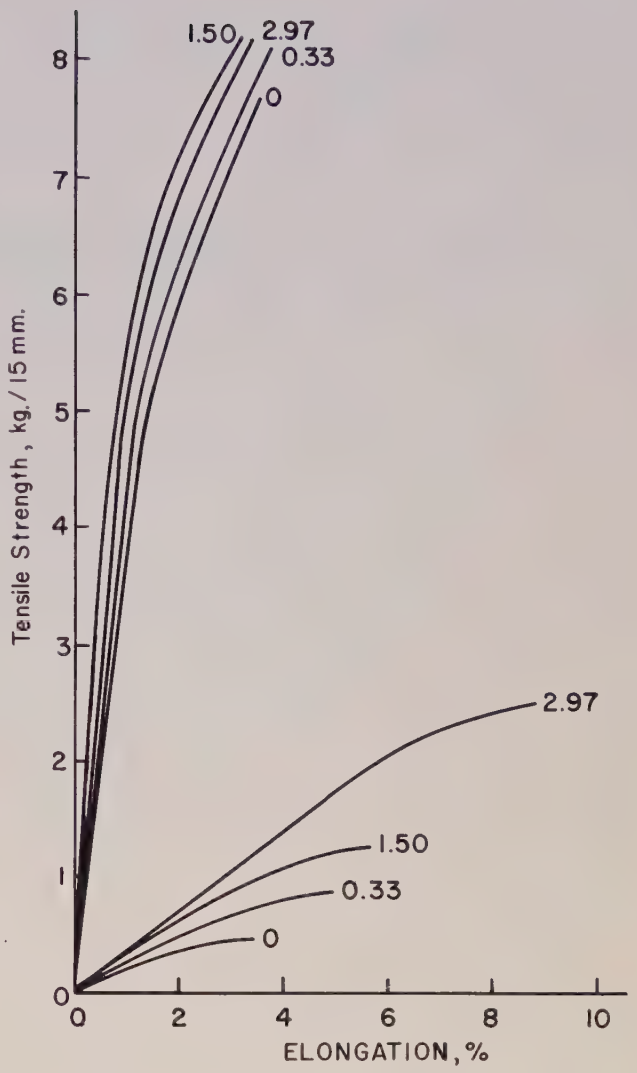

Fig. 2. Wet and dry stress–strain curves of unbleached kraft

The numbers on the curves indicate the percentage resin retained by beater-addition technique.

proof adhesive bonds. As the freeness increases or weaker sheets are formed by the use, for example, of bleached sulfite pulp, it is found that the differences between the increments in wet and dry strength with added resin become less noticeable; i.e., the resin functions more by adding bonds and there is less relative contribution from bond protection. Glass-fiber paper would represent an extreme case with virtually no protection contribution being possible. There was a tendency in every case for the dry strength to increase with increasing resin content to a maximum and then decrease again (e.g., Fig. 2). This being especially noticeable as the resin content begins to exceed about 3% retention. The flexibility of the fibers is greatly reduced at higher resin content and they are apparently less able to distribute the applied stress during testing. This results in a highly localized stress concentration in the breaking area causing a lower strength in spite of the increased bonding brought about by the resin.

In conclusion, it can be said that the views expressed in the previous two papers are confirmed by the additional experiments reported in this presentation. However, much further work is needed to establish the exact nature of the wet strengthening process.

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Beating, Interfiber Bonding, and Sheet Strength

FERDINAND WULTSCH and RUDOLF SCHMUT

This work is a study of the beating of pulp and the relation between beating and the properties of fiber fractions obtained in a Clark classifier, and the physical properties of handsheets. These handsheets were formed from the whole pulp and from fractions obtained in a Clark classifier at different beating intervals. Screen classification of pulp yields fractions that show rather constant physcial properties after initial beating. These physical properties remain the same despite progressive beating and changing properties of the whole pulp. A comparison of fractions from different beaters shows that the fractions compared exhibit similar properties; the whole pulps, however, are quite different from one anther. Pulps reach rather constant and characteristic physical properties after initial beating and removal of the fiber debris and the mucilaginous material. It is therefore possible to add strength-giving bonding materials before beating or after initial beating and to save considerably on power and beating time. This leads consequently to the possibilities of "chemical beating."

A survey of the literature showed an abundance of information on beating, refining, and strength development of pulps upon mechanical treatment (*1–9*). Our work was, therefore, organized to investigate and evaluate (1) the behavior of pulp upon beating in various laboratory and pilot plant beating apparatus, (2) the physical properties of some of the pulp samples, (3) a critical examination of fiber classification in screen classifiers, and (4) the comparison of properties of different pulp fractions obtained in a screen classifier.

The majority of other investigators centered their attention on a comparison of different pulps or of various pieces of equipment; therefore, we have limited this study to an investigation of one pulp and have attempted to point out certain basic relations explaining the behavior of pulps upon beating.

EXPERIMENTAL

Preliminary investigations led to the following experimental design:

1. The characteristics of a commercial bleached sulfite pulp were determined by a beater run according to TAPPI Standard procedures in a Valley beater.
2. The characteristics of another sample of this pulp were determined by a beater run in a Clark kollergang according to TAPPI Standard procedures.
3. The characteristics of another sample of the same pulp were determined by a beater run in a pebble mill according to TAPPI Standard procedures.
4. Samples of the pulp were taken at the beginning and the end of the hollander beating cycle, at each beating interval of the kollergang, and at each beating interval of the pebble mill; these samples were classified in a Clark classifier using a set of 14-, 30-, 50-, and 100-mesh screens.
5. The behavior of the Clark classifier was examined under varying conditions.
6. Handsheets were made from pulp samples obtained as follows:

   (a) At the beating intervals of the Valley beater.
   (b) At the beating intervals of the Clark kollergang.
   (c) At the beating intervals of the pebble mill.
   (d) From the four fractions of the classified unbeaten pulp.
   (e) From the four fractions of classified pulp at the end of the Valley beater run.
   (f) From the four fractions of classified pulp obtained at each beating interval of the pebble mill.

7. The formed handsheets were conditioned at 20°C. and 65% R.H. and tested for basis weight, caliper, bursting strength, Elmendorf tearing resistance, tensile strength, Schopper folding endurance, and apparent density (by calculation). Sheet formation and testing was according to TAPPI Standard procedures.
8. Samples of the pulp were beaten in a pilot plant conical refiner made by Escher-Wyss (*10*) and in a Streckerfiner.
9. Samples taken at different intervals from these pilot plant refiners were taken and classified.

RESULTS

Figure 1 shows the characteristics of the pulp upon beating in the Valley beater and Fig. 2 shows the characteristics of the pulp developed by beating in the Clark kollergang; the development of the pulp after beating in the pebble mill is shown in Fig. 3.

Screen classification requires selection of a suitable set of screens for separation into adequate fractions. If the first screen retains a majority of the fibers (65 to 75%), some of the shorter fibers are retained as well and the fractionation becomes unrepresentative. On the other hand, one only obtains short fibers in the short fractions. The duration of a classification run has a decided influence on the results; the duration of classifier runs require, therefore, careful control.

Figure 4 shows fiber length distribution of three disintegrated paper samples. One can conclude that offset printing paper contains more long fibers than the other two samples and that the sanitary tissue contains more short stock than the other two papers. A critical comparison or evaluation of papers, as here

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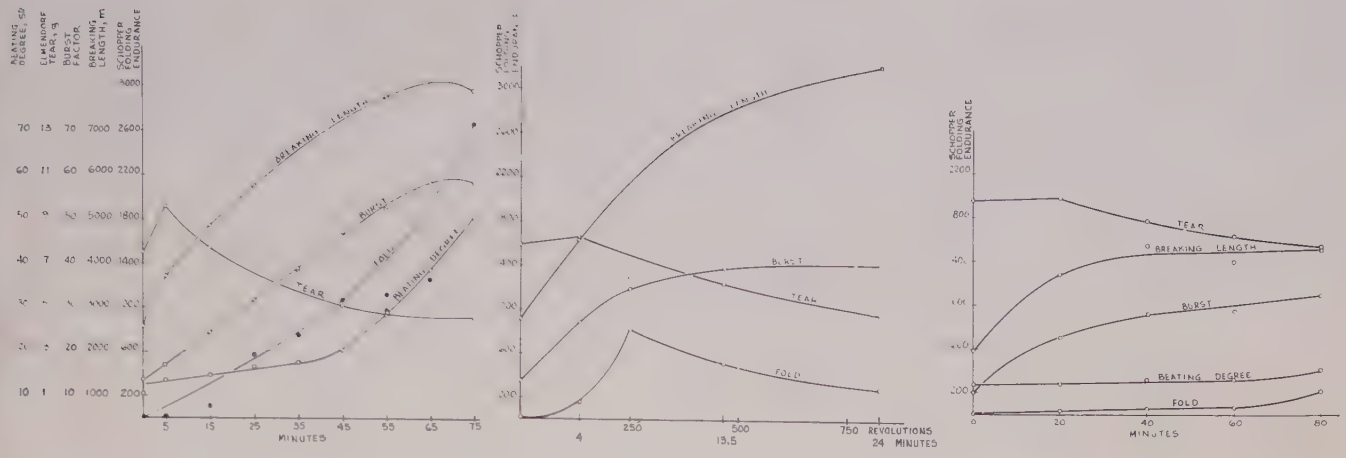

Fig. 1–3

between offset printing paper, sanitary tissue, and highly beaten glassine paper, is not possible.

Figures 5 and 6 show the comparative weights retained on the screens with progressing beating. Beating in the pebble mill is slow and almost exclusively hydrating; the Clark kollergang beats fast and cuts extensively.

Pilot plant runs on an Escher-Wyss conical refiner prove its predominantly cutting action; the Streckerfiner, on the other hand, acts most by bruising and hydrating. No basic difference was noted between fractionations of pulp samples beaten in laboratory beating apparatus and between pilot-plant scale beating in the Escher-Wyss refiner and the Streckerfiner. It is therefore permissible to transfer the findings for screen

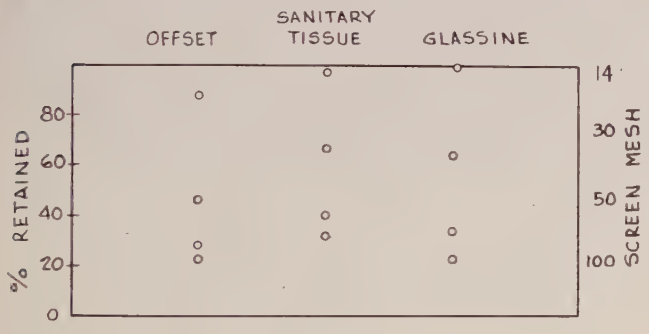

Fig. 4

classification from the laboratory to full plant-scale work.

We formed handsheets from the four fractions of unbeaten pulp, from fractions obtained after the end of the Valley beater run, and from pulp from all fractions obtained at all beating intervals of the pebble mill. Figures 7 to 10 show results from the physical testing of the handsheets conditioned at 20°C. and 65% R.H. These figures show the strength properties of the whole pulp compared with strength properties of the fractions: included are bursting strength, tensile strength, Elmendorf tearing resistance, and apparent sheet density.

The strength properties of the fractions reach characteristic values after an initial beating period and retain these values. This initial beating is interpreted as the interval during which the primary lamella starts to open and to be partially removed (*3*). The characteristic strength values of the fractions are reached after splitting the primary lamella and opening the surface of the secondary lamella.

Figures 11 to 14 give a comparison of strength properties of fractions after hollander beating with fractions obtained after beating in the pebble mill. It has been shown that upon beating in a pebble mill and subsequent screen classification the following constants result:

1. Weights retained on screens remained constant.
2. The fiber length distributions of the fractions

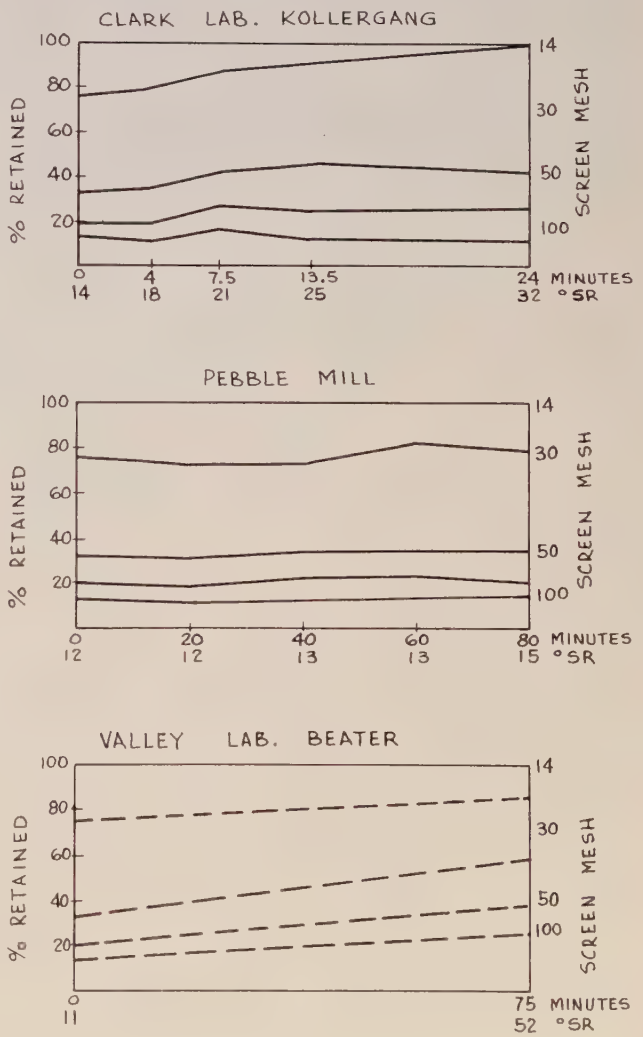

Fig. 5

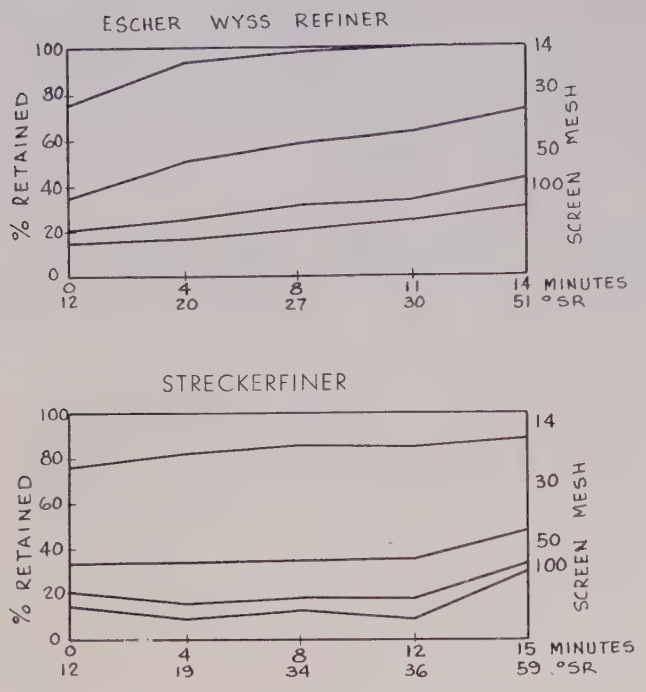

Fig. 6

remained constant and the average fiber length in the fractions remain constant (data are not included here).

3. The strength properties of the fractions remain constant. This proves that the fiber length distribution is giving a clear picture of the condition of the pulp.

The apparent density of the fractions remains constant after initial beating as well; slight increases can be attributed to the short duration of the classification runs in the Clark fiber classifier; one should consider increasing the duration of one run from the 4 min.

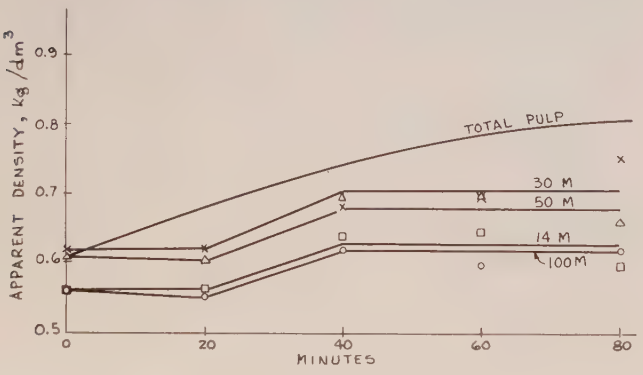

Fig. 7

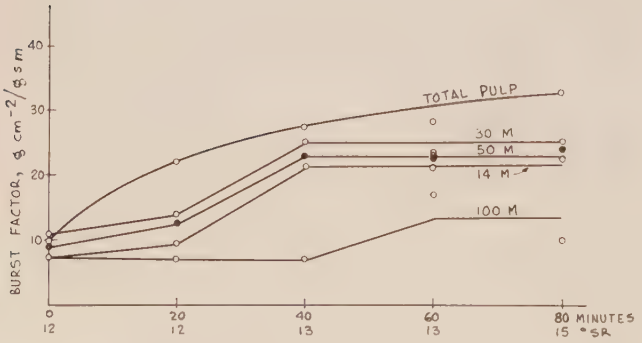

Fig. 8

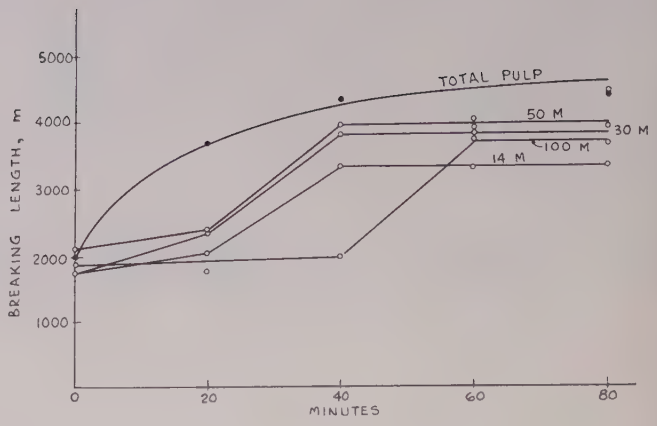

Fig. 9

commonly recommended to 5 or 6 min. After 4 min. there is still a certain amount of fiber debris and cellulosic mucilage retained.

Tensile strength and bursting strength of the long fibered fractions reaches the constant value faster than in the shorter fractions. The different behavior and the strength development of whole pulp and pulp fractions can be explained as the result of two different processes: The change in fiber length distribution measured as weights retained on the screens, and the increase of fiber debris and mucilage after opening of the primary lamella; these act in formation of the structure of the sheet and in interfiber bonding. The condition of the fibers and their surfaces seems to have only a constant influence after initial beating.

Tensile strength, bursting strength, and density of the whole pulp are higher than those of the fractions. Elmendorf tearing resistance shows directly and consistently the influence of fiber length (see Fig. 10). The longest fraction here surpasses constantly the whole pulp and all other fractions. Each fraction is stronger than the next shorter one. The behavior of the whole pulp is again a function of the different fiber length groups present, including fiber debris and mucilage.

Figures 11 to 14 show a comparison between the properties of whole pulp and of the fractions after 80 min. beating in a pebble mill and after 75 min. beating in a Valley beater. The static strength properties

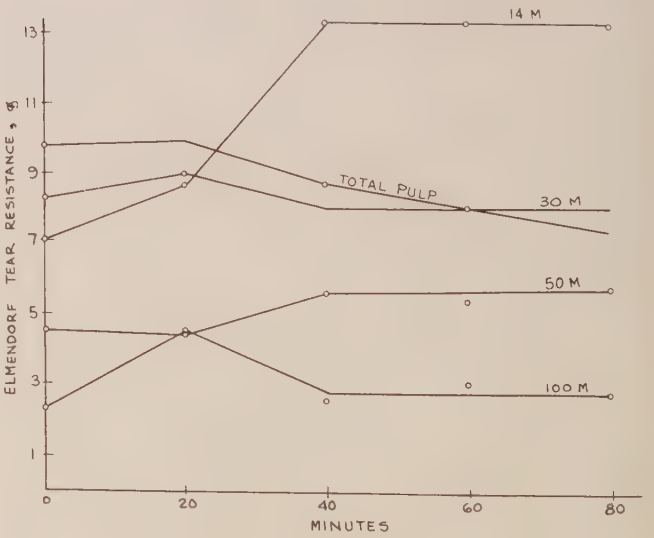

Fig. 10

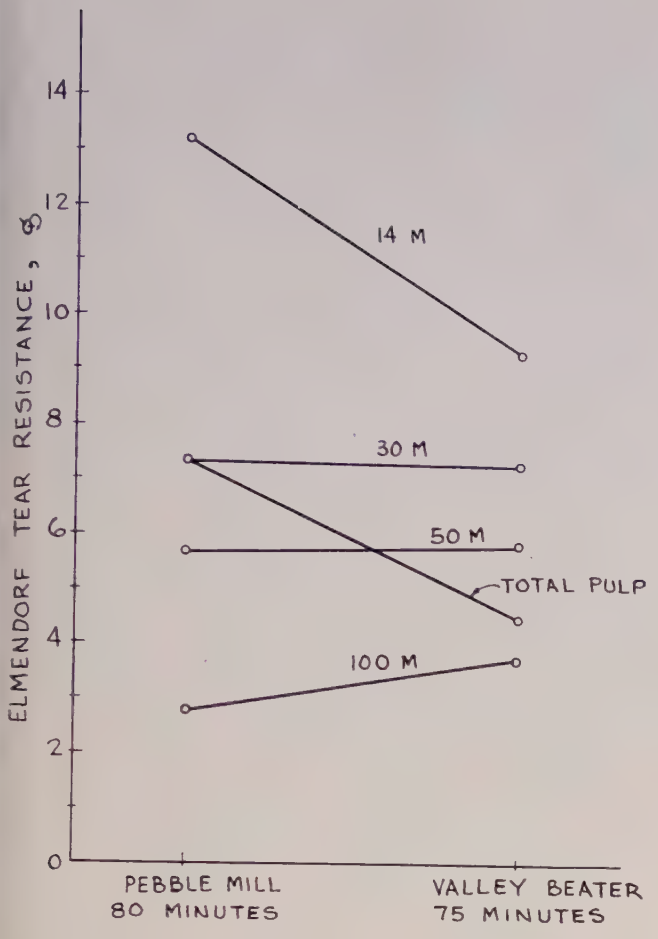

Fig. 11

show small differences between the fractions from the different beaters. The Elmendorf tearing resistance shows a highly significant behavior. Fractions 2, 3, and 4 of the pebble mill are almost identical to the fractions 2, 3, and 4 from the Valley beater. The stronger cutting action of the Valley beater is apparent in the differences between the whole pulps and between the first fractions.

It is mentioned below that freeness is unsatisfactory for describing the condition of a beaten pulp. Figure 15 shows the strength development of the studied bleached sulfite pulp, beaten in different beaters and presented as function of freeness; there is

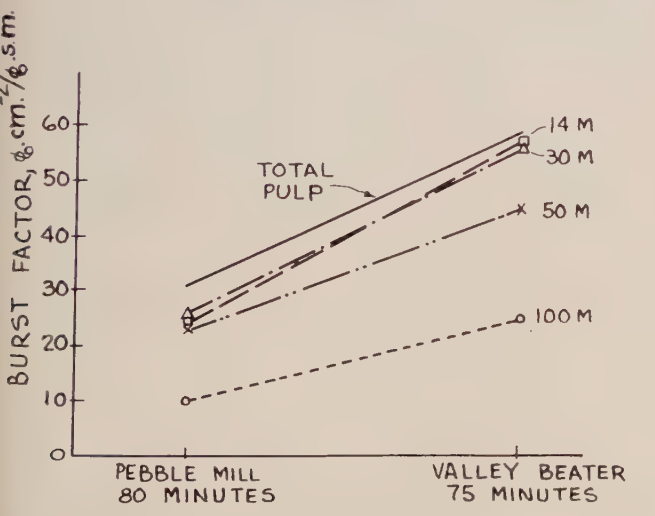

Fig. 12

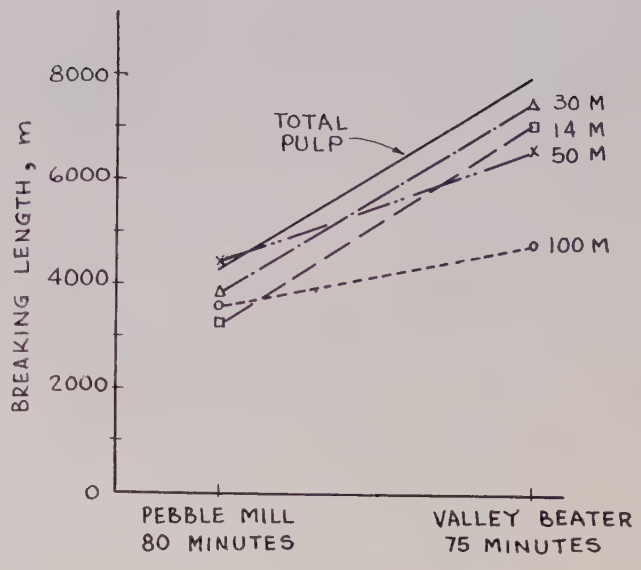

Fig. 13

no direct relationship evident between beating degree or freeness and the physical characteristics of the pulp. This result can be expected; strength development reflects generally swelling of the fibers during beating; freeness, however, is a function of the fiber surface and the debris and mucilage present. Freeness is useful as a tool, together with fiber length and fiber length distribution, to assist in the evaluation of pulps.

A critical examination of the presented work leads to the following conclusions:

CONCLUSIONS AND COMMENTS

Screen classification of pulp yields fractions that show rather constant physical properties after initial beating. These physical properties remain the same despite progressing beating and changing properties of the whole pulp.

The comparison of fractions from different beaters shows that the fractions compared exhibit similar properties; the whole pulps, however, are quite different from one another.

Pulps reach rather constant and characteristic

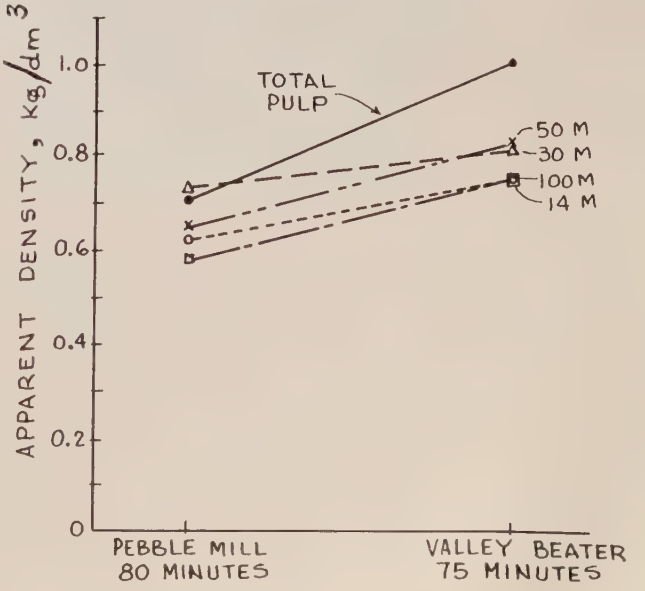

Fig. 14

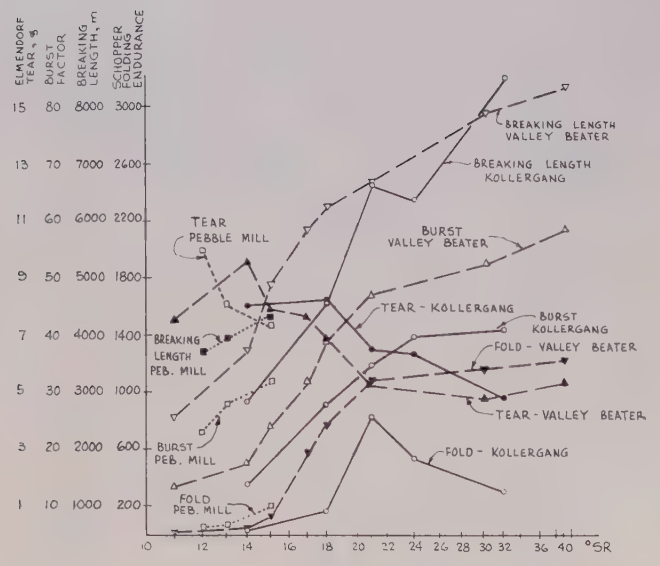

Fig. 15

physical properties after initial beating and removal of the fiber debris and the mucilaginous material. It is therefore possible to add strength-giving bonding materials before beating or after initial beating and to save considerably on power and beating time. This leads consequently to the possibilities of "chemical beating."

The pulp properties developed during beating depend on three main factors:

1. Fiber length distribution.
2. Individual fiber strength.
3. Strength of fiber-to-fiber bonds.

The standard freeness test does not distinguish between these effects, but fiber classification does.

Laboratory beaters differ markedly in their beating effects. The Clark kollergang produces within 7 min. the same fiber cutting as the Valley beater after 75 min. Pebble mills do not shorten fibers appreciably during the investigated cycle; Elmendorf tearing resistance indicates fiber length directly and easily and permits comparison of different beaters for their cutting action.

Our industry has used fiber length classification for the control of groundwood preparation. It has been shown that it can be used just as easily for chemical pulps. The fiber length classification in a screen classifier is for all practical purposes independent of the type of beater used. Therefore, it is particularly suited for comparative and critical investigations.

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Survey of Sampling and Precision Requirements in Present TAPPI Test Methods

CHARLES A. BICKING

A survey of TAPPI Standard Methods for testing pulp and paper revealed areas in which changes could be made to keep pace with advances in sampling theory, and in methods for measuring and expressing precision and accuracy of testing. Precision and accuracy are defined. Seven tables outline the information in present standards on sampling methods, on preparation of test specimens, and on precision and accuracy.

There is a constant and lively interest in the improvement of testing methods. One of the aspects of testing that has received a great deal of attention in recent years is precision. This and the related subjects of sampling and test specimen preparation have been under review because of the widespread application of statistical quality control in industry. Associations like the American Society for Testing Materials and TAPPI have had active projects such as defining precision and the related concept, accuracy, in operational terms, adopting sampling plans of known operating characteristics and designing procedures for interlaboratory testing.

There are various reasons for wanting to include in Standard Test Methods information regarding their expected precision. The advantages to be obtained are knowing how closely samples of material may be compared, and being able to tell how well a laboratory is doing in keeping testing results in line.

The following steps have already been taken under the TAPPI sponsored Research Project on Precision:

1. A thorough literature survey
2. An industry-wide survey to determine what kind of precision data are available, including an indication of the methods which are considered most important and are most widely used
3. Round-robin testing to verify available information and to fill-in the gaps.

These three steps have been completed or are well under way. The results of the literature survey are massive and will be published by the Association. Some of the most pertinent results of the industry survey

Charles A. Bicking, The Carborundum Co., Niagara Falls, N. Y.

Table I. Sampling Requirements of TAPPI Standard Methods for Testing Pulp

Test no.	Sampling section	Representative sample	Special method	Number of samples	Weight of sample, g.	Area of sample
T 200	X	X	Bored	1 or 3	360 or 450	4 sq. in./bale or cook
T 201	..	X	....	1	...	.....
T 202	..	X	.....	1	...	.....
T 203	..	X	.....	1	...	.....
T 204	X	..	Wet dry layers	1	5	2 × 4 in.
T 205	X	X	.....	3 or 1	50 or 100	4 sq. in./bale or cook
T 206	..	X	.....	1	...	.....
T 210	X	X	Strip or wedge	"Sufficient"	...	.....
T 211		X	.....	1	...	.....
T 212	.	X	....	1	...	.....
T 214	.	X	...	1	...	.....
T 215	..	X	....	1	...	.....
T 218	X	X	..	1	20	.....
T 219	.	X	.	1	...	.....
T 222		X	.	1	...	.....
T 223		X	....	1	...	.....
T 224	X	X	.....	1	450	4 sq. in.
T 225	X	.	.....	1	150	4 sq. in./bale or cook
T 226	..	X	....	1	...	.....
T 227	X	X	...	1	50–100	4 sq. in.
T 228	X	X	X	1	...	.....
T 229	..	X	.....	1	...	.....
T 230	.	X	.....	1	...	.....
T 232	.	X	.....	1	...	.....
T 233	..	X	.....	1	...	.....
T 234	.	X	.....	1	...	.....

The following methods do not include any mention of sampling: T 207, T 208, T 209, T 213, T 216, T 217, T 220, T 221, T 231, T 235.

Table II. Sampling Requirements of TAPPI Standard Methods for Testing Paper

Method T 400 is "Sampling Paper for Testing"

Methods calling for representative sample				*Methods making no mention of sampling*			
T 401	423	434	459	T 402	440	461	479
403	424	435	462	404	442	463	481
405	425	438	464	407	445	465	483
406	426	441	467	409	446	466	484
408	427	444	468	410	447	470	485
411	428	448	469	412	451	471	486
413	429	449	473	414	452	472	487
415	430	450	475	417	453	474	
418	431	454	480	436	455	476	
419	432	456	482	437	457	477	
421	433	458	488	439	460	478	

Table III. Sampling Requirements of TAPPI Standard Chemical Methods

Test no.	Sampling section	Representative sample	Percentage of lot	Weight
T 605	X	..	..	....
T 607	X	..	2–10%	....
T 611	X	..	10%	500-ml. sludge 60-ml. liquor
T 612	X	..	..	....
T 613	X	..	..	....
T 614	X	..	..	....
T 615	X	..	10%	100 lb.
T 616	X	..	10%	....
T 617	X	X	2%	100 lb.

The following methods do not include any mention of sampling: T 600, T 601, T 602, T 603, T 604, T 606, T 608, T 609, T 610, T 618.

Table IV. Test Specimen Requirements of TAPPI Standard Methods for Testing Pulp

Test no.	Weight	Area or volume	Tolerance	Number	Percentage of lot	Treatment	Reference
T 200	360 g.	.....	±5 g.	1	..	Composite samples	...
T 201	2 g.	..	.	1	..	.....	...
T 202	2 g.	.....	....	1	..	.....	...
T 203	10 g.	.....	....	1	..	Air-dry	...
T 205	24 g.	.....	±0.5 g.	1	..	Composite samples	T 220
T 206	1 g./100 ml.	.....	....	1	..	.....	...
T 207	2 g.	.....	....	1	..	.....	...
T 208	0.5 lb.	.....	....	1	..	Break-up	...
T 209	0.3 g.	.....	....	1	..	.....	...
T 211	5 g.	.....	....	1	10%	Composite samples	...
T 213	.....	2000 sq. cm.	....	1	..	.....	T 210
T 214	1 g.	.....	±0.02 g.	1	..	.....	...
T 217	.....	2 × 1½ in.	±1/16 in.	1	..	.....	...
T 218	4 g.	.....	±0.1 g.	1	..	.....	...
T 223	4 g.	.....	....	1	..	.....	...
T 224	450 g.	1 sq. in.	±5 g.	1	..	.....	...
T 225	75 g.	1 sq. in.	±0.5 g.	1	..	.....	...
T 226	1 g.	2–3 l.	....	1	..	Filter	...
T 227	24 g.	1 sq. in.	±5 g.	1	..	.....	...
T 229	.....	1 sq. cm.	....	1	..	.....	...
T 232	10 mg.	.....	....	1	..	.....	...
T 233	24 g.	.....	....	1	..	Disintegrate	...
T 234	.....	1 l.	....	1	..	.....	...

The following methods do not include any mention of test specimen: T 204, T 210, T 212, T 215, T216, T 219, T 220, T 221, T 222, T 228, T 230, T 231, T 235.

have been published (*1*). Round-robin testing is continuing with some of the more important tests under study.

A fourth step is reported in this paper: a survey of the pulp and paper testing standards to determine what they specify as to sampling, selection of test specimens, and testing precision.

Finally, it will be possible to incorporate valid precision information in useful form in the Standard Testing Methods.

GENERAL RESULTS OF SURVEY

The general impression derived from the complete survey is that, in most of the methods, sampling and test specimen preparation requirements can be made much more explicit and that such statements on

Table V. Test Specimen Requirements of TAPPI Standard Methods for Testing Paper

Test no.	*Weight, g.*	*Area or volume*	*Tolerance*	*Number*	*Treatment*	*Reference*
T 401	0.2	.....	.....	.....	.....	.....
T 403	..	2.5 × 2.5 in.	.....	.....	.....	T 400–402
T 404	..	9.9 × 0.5 in.	.....	.....	.....	T 402
T 405	3	.....	.....	.....	.....	.....
T 406	0.25	6 sq. mm.	.....	.....	.....	.....
T 407	..	25 sq. in.	.....	.....	.....	T 402
T 408	..	6 × 40 mm.	.....	.....	.....	.....
T 409	..	{2 sq. in. {0.5 × 6.0 in.	.....	{1 {2	.....	.....
T 410	..	{ 1 sq. ft. {100 sq. in.	.....	{ 1 (board) {10 (paper)	.....	T 402
T 411	..	2 in.	.....	.....	.....	T 402
T 412	2	.....	.....	.....	.....	T 400
T 413	1	.....	±1 mg.	.....	Dried to constant weight	.....
T 414	..	76 × 63 mm.	.....	.....	Slit 20 mm.	.....
T 415	0.5	.....	.....	.....	.....	.....
T 418	2	.....	.....	.....	.....	T 412
T 419	5	.....	±5 mg.	.....	Disintegrate	.....
T 421	0.15	.....	.....	.....	.....	T 407–413
T 423	..	15 mm. × 10 cm.	.....	10	.....	.....
T 424	..	"Sufficient"	.....	5	.....	.....
T 425	..	"Sufficient"	.....	5	.....	.....
T 426	..	2 in.	.....	10	.....	T 402
T 427	..	2 × 5 in.	±1/8 in.	6	.....	.....
T 431	..	4 × 4 in.	.....	1	.....	.....
T 432	..	4 × 4 in.	.....	1	.....	.....
T 433	..	2.5 sq. in.	.....	.....	.....	T 402
T 434	..	1/4 sq. in.	.....	.....	.....	.....
T 435	..	1 sq. cm.	.....	.....	Reduce to fluff	.....
T 436	5	1/8–1/4 sq. in.	.....	.....	Follow recipe	.....
T 437	..	320 sq. in.	.....	.....	.....	T 400
T 438	..	"Sufficient"	.....	.....	.....	T 412
T 440	3	1/4 × 1/4 in.	.....	.....	.....	.....
T 441	..	"Sufficient"	.....	10	.....	.....
T 444	..	6.5 sq. in.	.....	5	.....	.....
T 446	..	25 × 100 mm.	±0.05 mm.	12	.....	T 402
T 447	..	2 × 25 in.	.....	.....	.....	.....
T 448	..	.....	.....	2	.....	.....
T 451	..	15–50 × 75 mm.	.....	.....	.....	.....
T 452	..	2 × 1 1/2 in.	.....	.....	In pad form	.....
T 453	..	15 mm. × "sufficient"	.....	20	.....	.....
T 454	..	4 × 4 in.	.....	.....	.....	.....
T 456	..	Various	.....	.....	Conditioned	.....
T 457	..	Various	.....	.....	.....	T 402–404
T 458	..	0.05 × 4 in.	.....	.....	.....	T 402
T 459	..	"Convenient"	.....	.....	.....	.....
T 460	..	1 7/8 × 5 in.	.....	.....	.....	T 402
T 461	..	2.75 × 8.25 in.	.....	.....	.....	.....
T 462	..	2 × 2 in.	.....	.....	.....	T 400–402
T 463	..	5.5-in. long	.....	24	Two per roll	.....
T 464	..	.....	.....	2	.....	.....
T 465	..	"Suitable"	.....	.....	.....	T 400
T 466	..	Trapezoid	.....	.....	.....	T 402
T 467	..	3 × 8 in.	.....	4	.....	T 402
T 468	..	1 × 1 cm.	.....	.....	.....	.....
T 469	..	5 × 1 in.	±1/32 in.	.....	.....	T 402
T 470	..	15.0–35.4 mm. × 25.4 cm.	.....	.....	.....	T 402
T 472	..	Various	.....	5	Each direction	.....
T 473	..	.....	.....	3–5	Two methods	.....
T 474	..	2 1/8 × 2 1/8 in.	.....	2	.....	T 402
T 475	..	3 × 3 in.	.....	.....	.....	.....
T 476	..	4 in. wide	.....	3	Hole in middle	T 402
T 477	..	1 3/4 × 2 1/4 in.	.....	8	Several	.....
T 478	..	2 3/4 × 2 3/4 in.	±1/16 in.	20	.....	T 400
T 479	..	2 × 2 in.	.....	10	.....	.....
T 480	..	"Sufficient"	.....	.....	.....	T 402
T 481	..	6–18 × over 15 mm.	.....	.....	Cut per pattern	.....
T 482	..	6 × 6 in.	.....	.....	.....	.....
T 484	..	"Sufficient"	.....	.....	.....	T 412
T 485	..	72 sq. in.	.....	6	.....	T 400
T 486	..	2 × 2 in.	.....	5	.....	T 400
T 487	..	1 in.	.....	2	Cut at random	.....

The following methods do not include any mention of test specimen: T 400, T 402, T 417, T 428, T 429, T 430, T 439, T 442, T 445, T 439, T 450, T 455, T 471, T 483, T 488.

precision as can be found may be improved in clarity. Not only is the proportion of methods having explicit information of the character sought very small, but also, those in which attempts have been made to use statistically based information are not as complete nor as useful as they could be made. However, knowledge of the present status of the methods provides direction for study and a basis upon which improvement may be measured.

SUMMARY OF SAMPLING REQUIREMENTS

Table I to III summarize the information on sampling contained in TAPPI Standard Test Methods. Table I covers pulp tests, Table II paper tests, and Table III chemical methods.

There are 36 Standard Methods for testing pulp. Of these, only nine have a section dealing expressly with sampling. However, a total of 24 of the methods, including seven of the nine, call for the selection of a "representative" sample.

Detailed analysis of the nine sampling sections shows that three specify the sample size (i.e., number of specimens), seven specify the weight and six the area of the samples. One calls for a sample "of sufficient size." Four of the nine describe special handling requirements.

There are 85 Standard Methods for testing paper. The first of these is a Standard for "Sampling Paper for Testing." None of the other tests contains a separate sampling section; but 44 of them mention "representative" sampling.

There are 19 Standard Chemical Methods. Of these, nine have a section dealing expressly with sampling. One of the nine calls for a representative sample, five specify the percentage of the lot to be sampled, and three mention the weight of the sample.

SUMMARY OF TEST SPECIMEN REQUIREMENTS

Tables IV and V summarize the information on test specimens contained in TAPPI Standard Test Methods. Table IV covers pulp tests, and Table V paper tests. As for chemical methods, information on test specimens is so limited that it does not warrant tabulation.

Of the 36 pulp tests: 13 say nothing about the size of the test specimens; 19 specify the weight, and eight the area or volume of test specimens; although all are based on one specimen, only 13 mention this specifically; and one mentions the percentage of the lot to be tested. Special treatment of the specimens is spelled out in seven methods. Seven methods give tolerances on the specimen weight and one on specimen size.

Of the 85 paper tests: 15 have no requirement for test specimen size; 11 specify the weight of test specimens; 51 specify required area or volume and eight specify "sufficient," "suitable," or "convenient" area or volume; 27 mention number of specimens (presumably one specimen is implied for the rest). Special treatment is described in 14 of the methods. Two of the methods give tolerances on weight and four on size.

Of the 19 chemical methods, T 600 to T 618, only three include any mention of test specimen: T 609 specifies the weight in grams; T 615 calls for 600 g.; T 616 calls for about one quart and specifies crushing, mixing, quartering, and grinding to pass no. 10 screen.

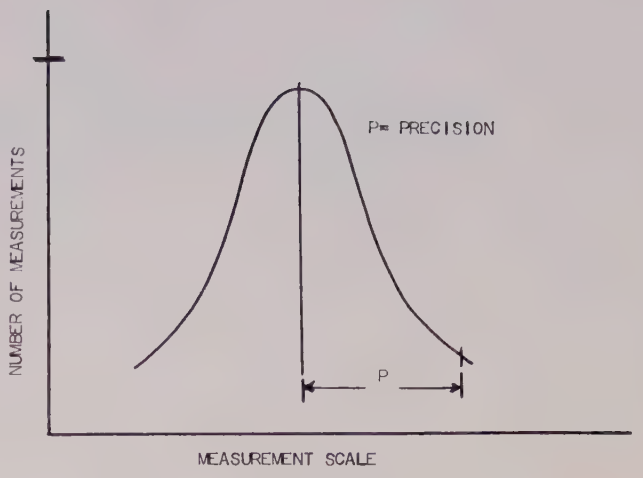

Fig. 1. Precision; distribution of test results

REVIEW OF THE CONCEPT OF PRECISION

Before proceeding to the summary of precision requirements in the Standard Test Methods, the general concept of precision measurement will be reviewed briefly (*2*, *3*). Precision of a test method is a measure of the extent to which independent, repeated measurements of a quantity cluster about their average.

Precision is a measure of the random, or nonsystematic variation in the measurement process. Any constant or systematic variation, or bias, is related to another property of the method, its accuracy. The measurement of a systematic variation requires the accepted reference or standard value outside of the measurement process. Accuracy consists of the bias (difference between the reference value and net average of a series of measurements) plus precision. Figures 1 and 2 represent the concepts of precision and accuracy.

The most generally accepted expression for the spread of measurements is their standard deviation. Since the greater the clustering the smaller the standard deviation, precision is inversely related to the size of the standard deviation. Although the standard deviation is a measure of precision, it is practical to define precision in terms of an interval which may be expected to include a given percentage of all measurements made by the method. If a satisfactory estimate of the standard deviation has been obtained, normal

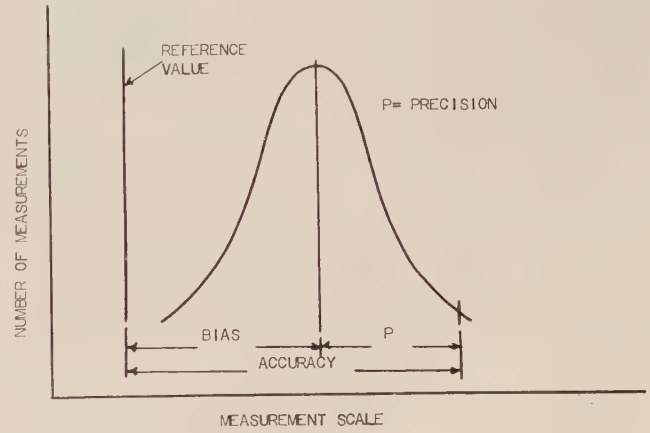

Fig. 2. Accuracy; distribution of test results

Table VI. Precision Requirements of TAPPI Standard Methods for Testing Pulp

Test no.	Agreement of duplicates[a]	Percent of average[a]	Range of results[a]	Accuracy[a]	No requirement expressed in tests numbered	
T 202	0.1 or 2%	...	.....	...	T 200	221
T 206	2% bleached	...	.....	...	201	222
	3% unbleached	...	.....	...	203	223
T 208	.....	...	.....	0.2 ml.	204	224
T 211	0.03	...	.....	...	205	226
T 212	10% same observer	2.5%	.....	...	207	227
	20% different observers					
T 214	0.1–0.5 single sample	...	.....	...	209	228
T 219	5%	...	.....	...	210	229
T 220	2%	...	57–63 g.s.m.	...	213	230
T 225	Burst factor, 5%	...	.....	...	215	231
	Breaking strength, 7%	...	.....	...	216	232
	Tear factor, 10%	...	.....	...	217	233
	Specific gravity, 5%	...	.....	...	218	234
	Drainage time, 7%	...	.....	...		235

[a] Operational meaning explained only where noted and probability levels not specified in any of the statements.

distribution theory provides the multiplier required to get the interval which will include the desired percentage of measurements. A multiplier of 3 will include "practically all" measurements and has proved to be satisfactory in use.

When it is desired to specify a standard for precision, it is necessary only to specify a value which shall not be exceeded. Thus, one may specify that precision shall be within 0.2 lb., meaning that the interval calculated as suggested, shall not exceed 0.2 lb.

In expressing accuracy, it is desirable to indicate whether the bias overestimates or underestimates the reference value. Thus, one might report that the accuracy of a method is 0.5 lb.; 0.3 lb. bias overestimate plus 0.2 lb. precision. When reporting either precision or accuracy, one should define the measurement process involved and state either the multiplier of the standard deviation or the probability level used.

Table VII. Precision Requirements of TAPPI Standard Methods for Testing Paper

Test no.	Agreement of duplicates[a]	Accuracy[a]	No requirement expressed in tests numbered		
T 403	5%	.....	T 400	445	475
T 406	5%	.....	401	446	477
T 405	0.2%	.....	402	449	478
T 407	....	0.5–2.0	406	452	479
T 410	2%	.....	408	453	480
T 411	0.0002 thickness	.....	409	454	481
	3% volume				
		0.05/5% ash	415	455	485
T 412	0.02	0.1/5–10% ash	417	456	486
		0.2/over 10% ash	418	459	487
T 413	....	.....	419	460	488
T 414	7%	.....	421	461	...
T 425	0.5	.....	423	462	...
T 426	3%	.....	424	463	...
T 431	5%	.....	427	465	...
T 432	5%	.....	428	466	...
T 433	10–15%	.....	429	467	...
T 435	0.1 pH	.....	430	468	...
T 437	10%	.....	434	469	...
T 441	10%	.....	436	471	...
T 447	2%	.....	438	472	...
T 448	10%	.....	439	473	...
T 450	0.4	.....	440	474	...
T 451	5%	.....	442	...	...
T 457	5%	.....	444	...	...
T 458	....	2–5%	...	...	...
T 464	20%	.....	...	...	...
T 470	5%	.....	...	...	...
T 476	10%	.....	...	...	...
T 482	10%	.....	...	...	...
T 483	2	.....	...	...	...
T 484	....	±0.1 ml.	...	...	...

[a] Operational meaning and probability levels not specified in any of the statements.

SUMMARY OF PRECISION REQUIREMENTS

Tables VI and VII summarize the information on precision contained in TAPPI Standard Test Methods. Table VI covers pulp tests and Table VII paper tests. The precision information in the chemical methods does not warrant tabulation.

Out of the total of 36 pulp tests: 27 make no statement about precision; eight specify the degree of agreement expected of duplicates; one mentions the tolerance as percentage of the average value; and one specifies the accuracy expected. In no instance, however, are the probability levels associated with the statements mentioned, and in only two instances are the conditions mentioned under which the statements apply.

Out of the total of 85 paper tests: 56 have no precision requirement; 25 specify the agreement of duplication; and four specify accuracy. As with the pulp tests, in no instance is information given on the applicability nor the probability levels associated with the precision.

Of the 19 chemical methods only one, T601, mentions precision, calling for agreement of duplicate tests within 2 ml.

CONCLUSIONS

No further analysis of the survey results is contemplated. Moreover, little useful information can be extracted beyond the facts summarized in the preceding sections and condensed in the tables. It is presumed that the few precision statements in the Methods are the results of study in many laboratories and of formal statistical analysis. It is unfortunate that even the information given is so ambiguous.

Unambiguous precision information on 13 of the most widely used pulp and paper tests is given in reference (*1*). "Applying Precision Standards," Part II of reference (*2*) is in preparation. It will provide a guide for use of valid precision information coming from carefully designed round-robin tests in future revisions of the TAPPI Standard Test Methods.

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Resistance of Wire Screens to Flow of Water

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By analogy with fluid flow through porous media and on the basis of experimental evidence, a correlation for screen resistance has been developed in a generalized dimensionless form. The correlation includes a viscous resistance characteristic of streamline flow and an inertial resistance representative of turbulent flow. The screen geometry is characterized by three quantities: screen thickness, specific surface, and void fraction, all of which can be either measured or calculated from the elementary dimensions of the wires composing the screen. The data upon which the correlation is based cover twill-weave screens from 35 to 100 mesh in the velocity range of 0.1–30 ft. per sec. The results of the correlation are discussed with respect to the sheet-forming process.

NOMENCLATURE

A	=	area, sq. ft.
A_0	=	open area, sq. ft.
a	=	a constant in viscous resistance term
a'	=	a constant in viscous resistance term
b	=	a constant in inertial resistance term
b', b''	=	constants in inertial resistance term
c	=	exponent
C	=	orifice discharge coefficient, dimensionless
D	=	diameter of pipe, ft.
d_s	=	diameter of shute wire, in.
d_w	=	diameter of warp wire, in.
f	=	friction factor, dimensionless
g_c	=	a conversion constant, 32.2
Δh	=	fluid head loss, ft.
k	=	a constant
L	=	screen thickness, ft.
L'	=	screen thickness, in.
m_1	=	slope in a plot
m_2	=	slope in b'' plot
n	=	exponent
n_s	=	no. of shute wires per in.
n_w	=	no. of warp wires per in.
ΔP	=	pressure drop, lb. per sq. ft.
q	=	volumetric flow rate, ft.^{3} per sec.
Re	=	Reynolds number, dimensionless
r_h	=	hydraulic radius, ft.
S	=	surface area per unit volume of screen, ft.$^{-1}$
U	=	approach velocity, ft. per sec.
u	=	pore velocity, ft. per sec.
α	=	coefficient of viscous resistance, dimensionless
β	=	a coefficient of inertial resistance, dimensionless
β'	=	a coefficient of inertial resistance, dimensionless
ϵ	=	void fraction, dimensionless
μ	=	fluid viscosity, lb. per ft. sec.
ρ	=	fluid density, lb. per ft.^{3}
ψ	=	pitch-diameter ratio, dimensionless
τ_0	=	shear stress at the surface, lb. per sq. ft.

FLUID flow through screens, grids, or fabrics has been extensively studied. Previous attempts at generalized correlations for the hydrodynamic resistance of these materials were based on simplified models of flow through orifices and around cylinders.

In his study of air flow through open-weave fabrics, Robertson (*1*) adopted the orifice model and accordingly correlated the discharge coefficient with the Reynolds number.

$$C = \frac{q}{A_0\sqrt{\frac{2g_c\Delta h}{1-(A_0/A)^2}}} = \phi\left(\frac{DU\rho}{\mu}\right) \qquad (1)$$

He found that at high flow rates, the discharge coefficient was larger than unity in contrast to a single orifice or nozzle.

Wieghardt (*2*) and Cornell (*3*) considered the flow around cylinders and attempted the use of drag coefficients. The latter compared round-wire-screen losses with single-cylinder drag coefficients and found a family of curves at low Reynolds numbers with fractional open area as a complex parameter. He also tried the orifice model and established the agreement of sharp-edged screens with the theory. His work indicated the importance of a three-dimensional viewpoint of round-wire screens.

Grootenhuis (*4*) adopted the three-dimensional concept and succeeded in correlating air flow through screens of square meshes in a single curve on a logarithmic plot of friction factor and Reynolds number in the form of

$$f = \frac{k}{Re^n}. \qquad (2)$$

As pointed out by Wooten (*5*), such a correlation would probably result in a family of curves with the pitch-diameter ratio as a parameter.

Bergström and Knell (*6*) proposed the correlation:

$$\Delta h = \frac{30}{(A_0/A)^2}U + 13\frac{(n_w n_s)^{0.3}}{(A_0/A)}10^{-4}U^2 \qquad (3)$$

where Δh was in mm. H_2O, A_0/A in %, U in cm.^{3}/(sec.)(m.)^2, and n_w, n_s in number of wires per in. It is obvious that their correlation is based on the Reynolds proposition, which is to be discussed later. The geometric factors introduced, however, are strictly empirical, and the numerical constants are dimensional and probably without much significance.

DEVELOPMENT OF A GENERAL CORRELATION

When a wire screen is placed across a fluid stream, the flowing fluid suffers from a loss of energy as manifested by a permanent pressure drop across the screen. The useful energy is dissipated as heat by virtue of frictional effects.

For flow of water through a wire screen with a uniform approach velocity, U, the pressure drop, ΔP, may be considered to be due to both viscous and inertial effects. According to the law of viscous flow, the pressure drop is directly proportional to the velocity. The frictional head loss in turbulent flow which is dominated by inertial forces, however, is known to be nearly proportional to the velocity squared. Thus, for a given screen, we may write

$$\Delta P = aU + bU^2 \qquad (4)$$

in which the two dimensional constants, a and b, are

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characteristic of the particular screen, and also dependent on fluid properties. This approach was first proposed by Osborne Reynolds (*7*) in his analysis of pipe flow, and has been quite successfully applied to flow through capillary tubes with entrance and exit losses, as well as flow through porous media.

To develop equation (4) to a useful correlation, fluid properties and screen geometry must be taken into account separately. The pertinent fluid properties are density and viscosity. The viscous forces are proportional to μU and the inertial forces to ρU^2. Therefore, a is proportional to μ and b to ρ, and equation (4) assumes the following form:

$$\Delta P = a'\mu U + b'\rho U^2 \qquad (5)$$

where a' and b' are two new constants characteristic of the screen structure only.

In the present development, the wire screen is considered as an elementary layer of a porous medium. This incorporates Grootenhuis' concept of a three-dimensional structure in contrast to the prevailing two-dimensional one. Furthermore, a general correlation for porous media has been successfully established by Carman (*8*), Leva (*9*), Ergun (*10*), etc., and applied to fiber mats by Ingmanson (*11*). Finally, it is thought that in this way flow through a fiber structure and a wire structure may be brought closer together for the future study of the sheet-forming process.

It is apparent that for a three-dimensional structure, the screen thickness must first enter into consideration. For an impressible material, the simplest incorporation of thickness into equation (5) is the use of an overall pressure gradient, $\Delta P/L$.

The surface area of the wires composing the screen contributes significantly to frictional effects. The specific surface, S, may be defined as the surface area exposed to flow per unit volume of screen. In the hydrodynamic treatment of porous media, the inertial effects are found to be proportional to S and the viscous effects to S^2.

The void fraction or porosity, ϵ, characterizes the average velocity in the open meshes of a screen, and, therefore, the general pattern of flow. For porous media, it is commonly agreed that both viscous and inertial effects are inversely proportional to ϵ^3, although some other functions have been suggested.

From the above discussion, it follows that

$$a'\alpha\frac{S^2}{\epsilon^3} \quad \text{and} \quad b'\alpha\frac{S}{\epsilon^3} \qquad (6)$$

Incorporating L, ϵ, and S into equation (5) and using g_c for converting absolute to engineering units, we obtain

$$\frac{g_c\Delta P}{L} = \frac{\alpha\mu S^2 U}{\epsilon^3} + \frac{\beta\rho S U^2}{\epsilon^3} \qquad (7)$$

where α and β are now two dimensionless constants, presumably common to all screens. All simple factors pertaining to flow through screens have now been taken into account.

Equation (7) can be rearranged by introducing certain dimensionless groups. As first proposed by Blake (*12*), a modified Reynolds number may be defined for wire screens, using hydraulic radius, r_h, as a characteristic length and average pore velocity, u, as a characteristic velocity. Thus,

$$Re = r_h\rho u/\mu. \qquad (8)$$

The hydraulic radius is considered to be the ratio of void volume to wetted surface,

$$r_h = \epsilon/S. \qquad (9)$$

The pore velocity is approximately related to the approach velocity by

$$u = U/\epsilon \qquad (10)$$

and consequently,

$$Re = \rho U/\mu S. \qquad (11)$$

Referring to the right side of equation (7), the first term represents viscous forces and the second, inertial forces. The ratio of the second to the first term is equivalent to the Reynolds number, defined by (11), the only difference being a constant number of β/α. This agreement also serves to show the proper dimensional relationship of the specific surface involved in both terms.

The pressure drop may be related to the shear stress on the wetted surface of the wires by a force balance similar to flow in a pipe

$$\Delta P A\epsilon = \tau_0 SAL \qquad (12)$$

where A is the total cross-sectional area of the screen. If a modified friction factor is introduced as originally suggested by Blake (*12*) for porous media,

$$f = \frac{g_c\tau_0}{\rho u^2} = \frac{g_c\Delta P\epsilon^3}{LS\rho U^2}. \qquad (13)$$

We may arrive at the conclusion that f should be some function of Re as a generalized correlation. This functional relationship is provided by equation (7). By rearrangement we have

$$\frac{g_c\Delta P\epsilon^3}{LS\rho U^2} = \frac{\alpha\mu S}{\rho U} + \beta, \quad \text{or} \quad f = \frac{\alpha}{Re} + \beta. \qquad (14)$$

The present development of a general correlation parallels essentially that of Ergun (*10*). However, Carman (*8*) found that the inertial resistance factor, β, for porous media is a true constant only over a limited velocity range, and he proposed that it be empirically expressed as a function of Reynolds number,

$$\beta = \beta'/(Re)^c. \qquad (15)$$

The value of the exponent, c, was found by Carman (*8*) and later by Leva (*9*) to be about 0.1, and the constant, β', to be from 0.4 to 0.5 for various porous media. Therefore, over a wide range of Reynolds numbers, equation (14) would become

$$f = \frac{\alpha}{Re} + \frac{\beta'}{(Re)^c}. \qquad (16)$$

This equation will serve as the basis for correlating the experimental data for flow of water through wire screens.

EVALUATION OF SCREEN GEOMETRY

In the development of the correlation, the screen geometry is specified by L, S, and ϵ. These quantities can be related by their definitions to the elementary dimensions of the wires of which a screen is composed. The elementary wire dimensions from which a simple screen geometry may be built up are only two: the

Table I. Measurement of Twill-Weave Wire Dimensions

Screen no.	n_w, warps/in.		n_s, shutes/in.		d_w, in.		d_s, in.	
	Spec.[a]	Meas.	Spec.	Meas.	Spec.	Meas.	Spec.	Meas.
1	100	100.0	96	94.3	0.005	0.00461	0.006	0.00598
2	100	100.3	94	94.7	0.006	0.00461	0.00625	0.00602
3	100	100.0	92	92.7	0.005	0.00480	0.00625	0.00642
4	100	100.3	92	92.7	0.005	0.00480	0.006	0.00602
5	78	78.2	72	71.0	0.00675	0.00642	0.0075	0.00752
6	74	74.0	62	62.7	0.0072	0.00685	0.008	0.00803
7	74	74.0	58	57.3	0.0072	0.00681	0.009	0.00906
8	74	74.0	58	58.0	0.0072	0.00681	0.0085	0.00844
9	74	74.0	58	57.7	0.0072	0.00681	0.0085	0.00842
10	70	70.0	56	56.0	0.0075	0.00709	0.00875	0.00850
11	68	68.0	54	53.7	0.008	0.00764	0.00975	0.00976
12	64	63.0	51	51.2	0.00875	0.00842	0.0105	0.00965
13	64	63.0	46	45.3	0.00825	0.00842	0.0105	0.01043
14	54	54.0	35	33.7	0.01075	0.01043	0.0135	0.01287

[a] Spec. = specified; meas. = measured.

diameter in inches and number of wires per inch. For square meshes they are the same in the major plane directions. In the more common case of rectangular meshes, these two dimensions must be specified for warps and shutes separately.

The manufacturers' specifications of wire meshes in warps and shutes are usually given in round numbers. For the fourteen screens of twill weave used in this study, a comparison of the specifications with the actual counts on 3-in. strips are shown in Table I. They are in very close agreement with each other.

The diameter of wire before weaving is held to a tolerance of about ±5%. However, in the process of weaving, the wires are deformed, resulting in non-uniform cross sections. Since the warps are subjected to high stresses, especially tension, they have appreciably smaller diameters after weaving. The results of microscopic measurements on the same 14 screens are included in Table I to compare with the original specifications. The measured diameters are average values taken systematically but arbitrarily at a number of points on a screen sample.

The thickness of a screen at a point where a warp and a shute are in contact and without deformation is simply the sum of the two diameters:

$$L = \frac{1}{12}(d_w + d_s). \tag{17}$$

As measured by a micrometer, the result represents the maximum thickness which is always somewhat larger than the point thickness calculated from equation (17). A comparison of these two thicknesses is shown in Table II.

If all the wires are uniformly cylindrical and in point contact, the wetted surface per unit screen volume can be calculated from the wire dimensions.

$$S = \frac{\pi}{L}(n_w d_w + n_s d_s) \tag{18}$$

Using all measured values, the specific surface so calculated is shown in the second column of Table II. It would be very desirable to check the calculated results against some measured values. There are several possible methods of measuring surface area of wires, such as electroplating and monolayer deposition.

The void volume per unit screen volume commonly called void fraction or porosity can be determined experimentally by water displacement or calculated from the following relationship:

$$\epsilon = 1 - \frac{\pi}{48L}(n_w d_w^2 + n_s d_s^2). \tag{19}$$

Both the calculated and measured values are shown in Table II. With most screens, the agreement is good.

It is quite obvious that L, S, and ϵ alone are not quite adequate to describe the screen geometry completely. In the field of textiles, wiggle, crimp, and other factors are sometimes introduced to specify the construction of woven fabrics. As suggested by Wooten (*5*), pitch-diameter ratio might be used for further characterizing a woven screen to account for the crimp of the warp wires. For square meshes of equal wire diameters, the pitch-diameter ratio is defined as

$$\psi = \frac{1}{d_w n_s}. \tag{20}$$

With papermaking screens, it is thought that the unequal diameters of the warp and shute should be

Table II. Characterization of Screen Geometry

Screen no.	L', in.		S, sq. ft./cu. ft.	ϵ	
	Calc.[a]	Meas.	Calc.	Calc.	Meas.
1	0.0106	0.0127	3,040	0.661	0.643
2	0.0106	0.0124	3,150	0.648	0.615
3	0.0112	0.0127	3,190	0.622	0.632
4	0.0108	0.0124	3,160	0.640	0.631
5	0.0139	0.0161	2,430	0.648	0.635
6	0.0149	0.0178	2,140	0.670	0.652
7	0.0159	0.0183	2,110	0.651	0.646
8	0.0157	0.0185	2,090	0.658	0.652
9	0.0152	0.0185	2,040	0.681	0.677
10	0.0156	0.0193	1,900	0.693	0.676
11	0.0174	0.0251	1,830	0.668	0.643
12	0.0171	0.0217	1,780	0.666	0.652
13	0.0188	0.0228	1,660	0.677	0.665
14	0.0233	0.0301	1,250	0.701	0.683

[a] Calc. = calculated; meas. = measured.

taken into consideration. This ratio is tentatively modified to

$$\psi = \frac{1}{(d_w + d_s)n_s} = \frac{1}{12Ln_s}. \qquad (21)$$

The pitch-diameter ratio calculated according to this definition, using the measured thickness, varied from 0.83 to 0.99 for the 14 screens in Table I.

Even if the geometry of wire screens can be adequately described, there remain differences of construction and wire-surface characteristics. The types of weave: plain, twill, monoplane, twisted cable, triple chain, etc., can be an important factor in screen hydrodynamics. The last two types are radically different from the first three and will probably require special treatment. The beads on warp wires probably have a minor effect on resistance.

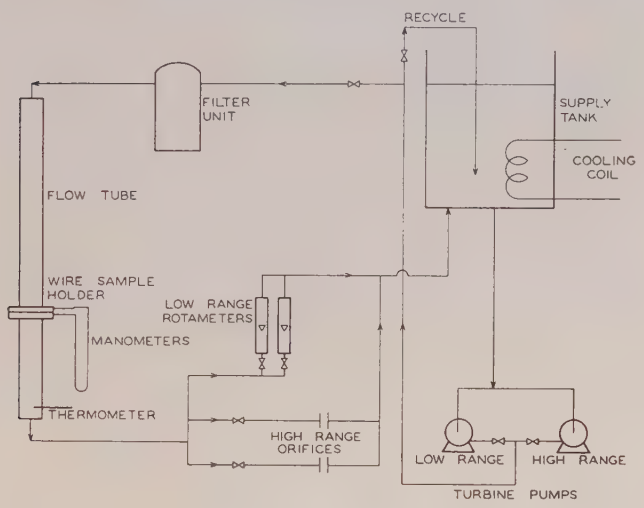

Fig. 1. Wire screen flow apparatus

The surface characteristics of wires may not be a significant factor, if the conventional wire materials can all be considered to be hydrodynamically smooth. However, a used screen having rough surfaces will tend to increase the resistance. The study reported here is limited to new screens of twill weave with bronze warps and brass shutes.

EXPERIMENTAL APPARATUS

The experimental apparatus used in obtaining the flow data consisted essentially of a flow system in which water, at measured rates, was pumped through a flow tube containing the wire specimen. The pressure drop across the screen was measured with suitable manometers.

Three different flow tubes were used to cover a range of fluid velocities from 0.1 to 30 f.p.s. In the low range (0.1 to 0.5 f.p.s.) a specially-designed 3-in. i.d. Lucite flow tube with a straightening section was used. In the intermediate range (0.4—6 f.p.s.) a straight section of 3 in. i.d. Lucite tube about 6 ft. long was used, and the high-range data (2 to 28 f.p.s.) were obtained by inserting a 2 ft. long, 1-in. i.d., brass tube into a flanged section of the 3-in. Lucite tube.

A schematic diagram of the apparatus is shown in Fig. 1 with the details of the low-range flow tube shown in Fig. 2. Two problems in the design of this apparatus were given particular attention. First, in the low flow-rate range, it is necessary that as nearly uniform as possible a velocity distribution be maintained at the upstream face of the wire sample. This was accomplished by a straightening section consisting of nineteen $^1/_4$-in. copper tubes in a uniformly spaced parallel arrangement. Velocity distributions with this flow straightener were checked by making pitot tube traverses at the upstream section of the wire sample. Above a tube Reynolds number of about 2000, the velocity distributions were found to be nearly symmetrical and uniform. This tube Reynolds number corresponds to an average velocity of about 0.1 f.p.s.,

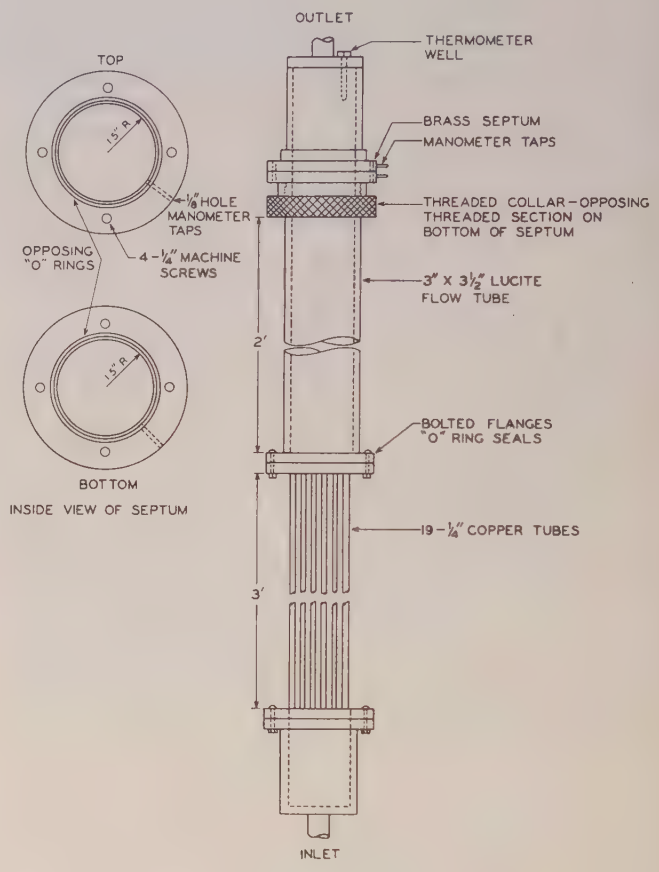

Fig. 2. Low-velocity range flow tube

which was the lowest velocity studied. The second problem involved the accurate determination of relatively low pressure drops across the wire samples in the low flow-rate range. Magnification of the low-pressure drops was achieved by using a two-fluid differential manometer system. The first fluid was water and the second was water-saturated diethyl phthalate having a measured specific gravity of 1.115 at 25°C. This manometer was read to the nearest 0.05 mm. with a cathetometer.

The section of the flow tube containing the wire sample was made of Lucite tubing with a 3-in. i.d. The screen was held on the septum in a flanged joint between two sections of the Lucite tubing and was sealed by O-rings. The complete flow tube including the straightening section was placed in a vertical

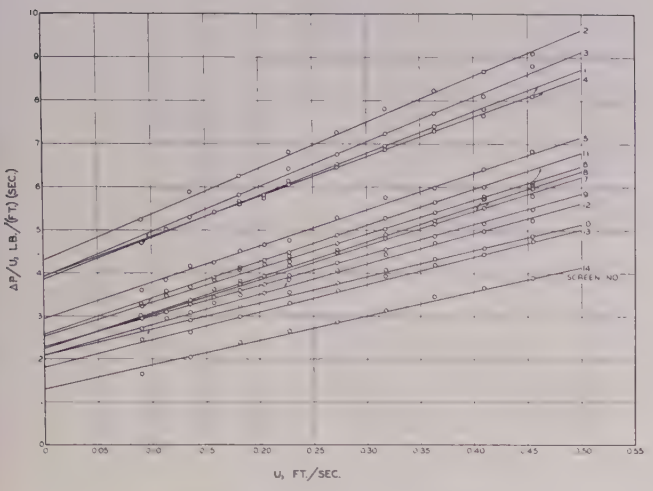

Fig. 3. Low-velocity flow data

position with the screen sample near the top to facilitate removal of air bubbles during the start-up.

Deionized and deaerated water was pumped from the feed tank through a set of cotton cartridge filters, through the flow tube, a rotameter or orifices and back to the tank. Two turbine-type pumps were used with capacities of 15 and 150 g.p.m. at heads of 100 p.s.i. for low- and high-range velocities, respectively. The water temperature was kept constant by a cooling coil in the 500-gal. supply tank. The temperature was measured with a mercury thermometer located in the flow tube and was constant in all runs at 74 ± 2°F.

Circular screen samples were cut and cleaned by soaking in acetone, scrubbing with a detergent solution,

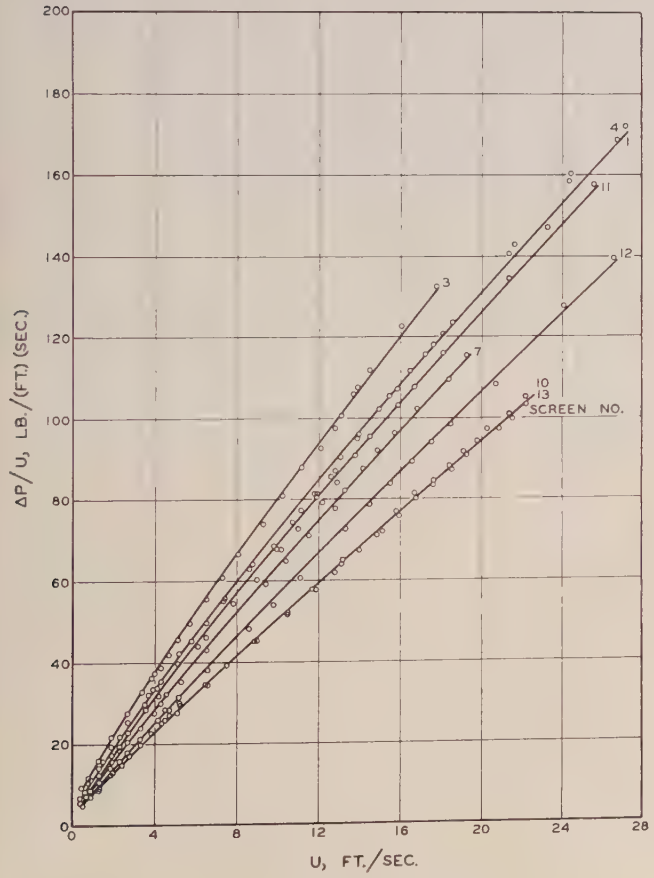

Fig. 4. High-velocity flow data

and finally rinsing with distilled water. The clean screen was carefully placed with the papermaking side downward in the septum held in the flanged joint of the lower section of the Lucite tube. The pump was started and the flow regulated by means of throttling valves. A manometer reading was taken when steady-state conditions were reached, and a complete run consisted of a number of evenly spaced flow rates starting from the lowest and going progressively to the maximum. In the intermediate and high-flow ranges water-carbon tetrachloride and water-mercury differential manometers were used, respectively. Data of pressure drop versus flow rate formed smooth curves over the entire velocity range from 0.1 to 30 f.p.s. with

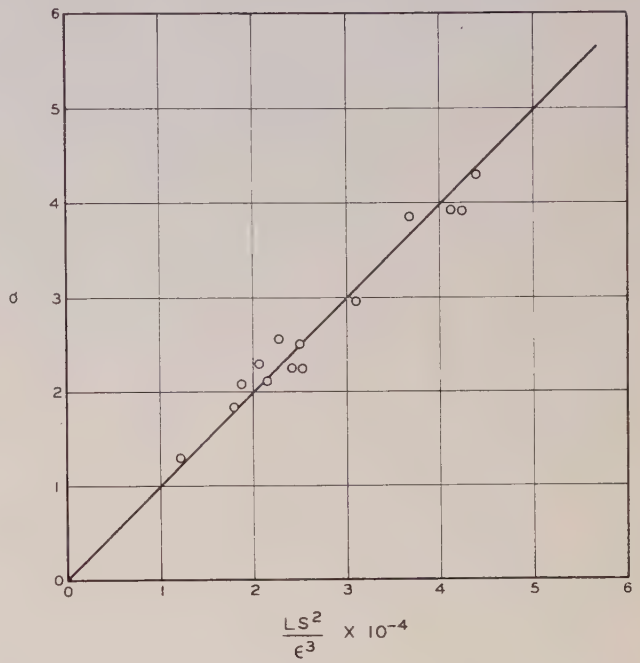

Fig. 5. Evaluation of viscous resistance

the three separate flow tubes indicating no unusual wall effects.

RESULTS AND DISCUSSIONS

The flow data determined in the low-velocity range (0.1 to 0.5 f.p.s.) were used to calculate the viscous resistance and the data over the intermediate and high range (0.4–30 f.p.s.) were analyzed to characterize the inertial resistance. Equation (4) may be rearranged to give

$$\frac{\Delta P}{U} = a + bU \qquad (4)$$

from which a plot of P/U versus U should be linear over a limited range of velocities and curved over a wide range of velocities. This is confirmed by the experimental data which are given at low velocities for all 14 screens in Fig. 3 and at intermediate and high velocities for eight of the screens in Fig. 4. The intercepts, a, and slopes, b, were used in the following manner to determine the dimensionless parameters, α and β, which represent the viscous resistance characteristic of streamline flow and the inertial resistance characterizing turbulent flow, respectively.

Viscous Resistance

Comparing equations (7) and (4), we have

$$a = \left(\frac{\alpha\mu}{g_c}\right)\left(\frac{LS^2}{\epsilon^3}\right) \tag{22}$$

and

$$b = \left(\frac{\beta\rho}{g_c}\right)\left(\frac{LS}{\epsilon^3}\right) \tag{23}$$

where the quantities in the first parentheses are constant and those in the second represent the effects of screen geometry on the viscous and inertial terms of equation (7), respectively. The data in Fig. 3 show b apparently constant over a narrow velocity range, but Fig. 4 shows b to be decreasing with increasing velocities over a greater range of velocities.

The viscous and inertial resistance dimensionless parameters were evaluated from the screen geometry, using measured values in Table II. The screen constants, a and b, from the low-range velocity data in Fig. 3 were plotted, respectively, with the parameters (LS^2/ϵ^3) and (LS/ϵ^3). It was found that the intercepts, a, were in good agreement with equation (22), whereas the slopes, b, showed more scatter, especially with the larger values. Since the inertial resistance represented by b is not a true constant, the data over the whole velocity range were used to determine its variation with velocity in the next section.

The dimensionless constant α representing the viscous resistance was determined from the slope m_1 of the intercept, a, plot in Fig. 5 where

$$\alpha = m_1\left(\frac{g_c}{\mu}\right). \tag{24}$$

At the experimental temperature, μ has a value of 0.624 $\times 10^{-3}$ lb. per (ft.) (sec.) and $\rho = 62.3$ lb. per cu. ft. Therefore, α from Fig. 5 is equal to 5.15.

The generally accepted experimental value for most incompressible porous media in the same porosity range as the wire screens is about 5, which compares favorably with the above value determined for wire screens. The openings in the wire screens were rectangular in shape with varying heights and widths of the rectangles. It was thought that the variation in height-to-width ratio of the rectangles might lead to variation in α which is equivalent to the Kozeny factor defined by Carman. The data of Carman (*8*) were used to estimate this possible effect on Kozeny factor, and it was found for the screens studied here that the height-to-width ratio of the openings, which varied from 1.1 to 1.6, would give only about a 5% variation in Kozeny factor. The experimental data are not precise enough to determine this relatively small variation. Therefore, the constant value of α indicated by the data appears reasonable.

Recently, Happel (*13*) used a free surface model based on modification of the unit-cell technique to solve the Navier-Stokes equations for viscous flow relative to arrays of cylinders. He expressed his results numerically by calculating the Kozeny factor in two cases for flow perpendicular and parallel to the cylinders. The experimental value of 5.15 determined in this study agrees well with those predicted theoretically by Happel for an average porosity of about 0.65.

Other data for plain and twill-weave wires with meshes from 20 to 200 were found to agree well with the viscous resistance factor α equal to 5.15. However, if wires had wider ranges of porosities, including higher porosities, it would be expected that α would be porosity dependent as found for other porous media.

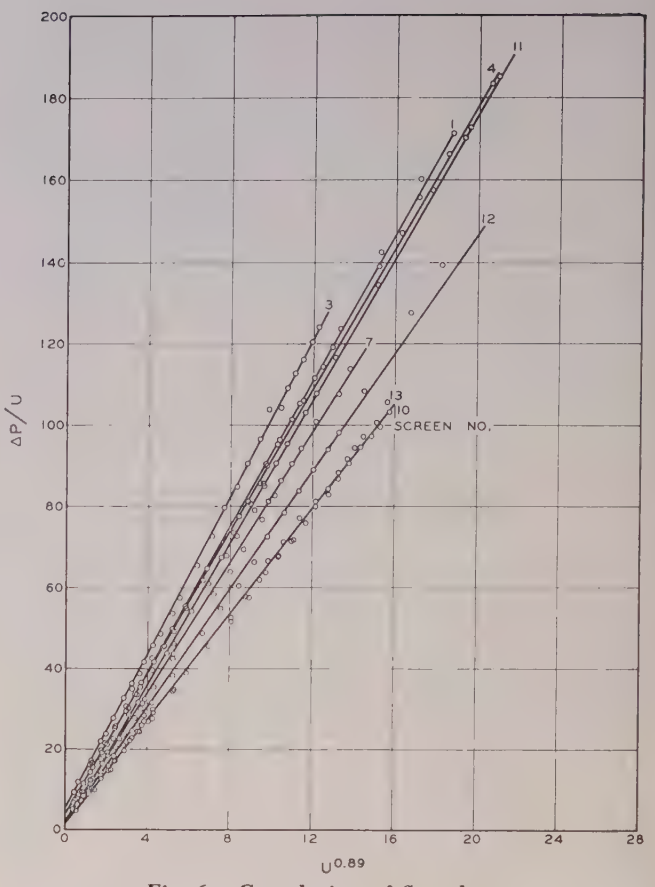

Fig. 6. Correlation of flow data

Inertial Resistance

Relating equations (23) and (15) gives the inertial resistance as a function of velocity:

$$b = \left(\frac{\beta'\rho}{g_c}\right)\left(\frac{\mu S}{\rho}\right)^c\left(\frac{LS}{\epsilon^3}\right)\left(\frac{1}{U^c}\right). \tag{25}$$

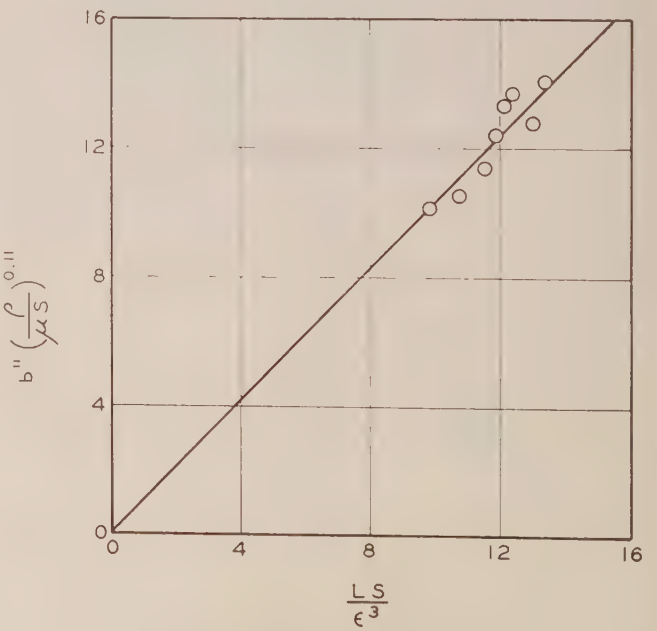

Fig. 7. Evaluation of inertial resistance

First, the slopes of the curves from Fig. 4 were used to calculate the value of the exponent c by combining equations (25) and (4) in the form

$$\ln \frac{d(\Delta P/U)}{dU} = -c \ln U + \text{const.} \qquad (26)$$

The average value of the exponent for the eight screens was found to be 0.11. Now equations (25) and (4) may be combined to give

$$\frac{\Delta P}{U} = a + b'' U^{0.89}. \qquad (27)$$

This equation is shown graphically in Fig. 6 where it is seen that the slopes b'' are now constant and inde-

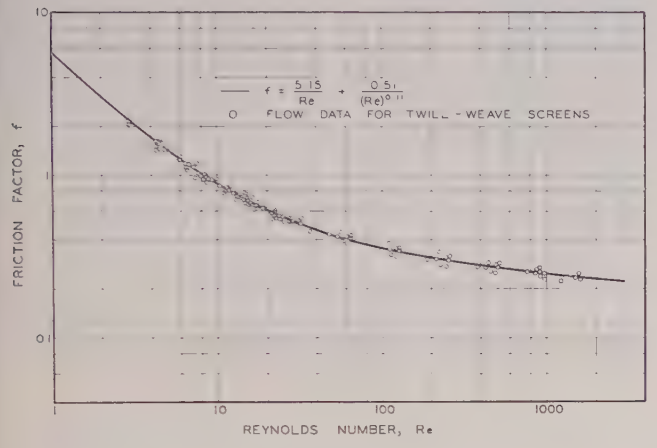

Fig. 8 Generalized correlation for flow through wire screens

pendent of velocity. Values of the slopes b'' were analyzed graphically in Fig. 7 to determine the inertial resistance factor β', since

$$b'' = \left(\frac{\beta'\rho}{g_c}\right)\left(\frac{\mu S}{\rho}\right)^{0.11}\left(\frac{LS}{\epsilon^3}\right). \qquad (28)$$

The value of the slope, m_2, from Fig. 7 was used to calculate β' from

$$\beta' = m_2\left(\frac{g_c}{\rho}\right) \qquad (29)$$

and β' was found to be 0.51. Thus, the empirical constants in equation (15) are given by

$$\beta = 0.51/(Re)^{0.11} \qquad (15)$$

for the wire screens tested in this study.

In other studies of flow through porous media, values of β' and c were found by Carman (*8*) for a variety of porous media to be 0.4 and 0.1, respectively, up to Reynolds numbers of 10,000 whereas Leva (*9*) obtained values of 0.51 and 0.1, respectively, for beds of spheres, cylinders, and brass rings over a Reynolds number range of 50 to 4000. These values agree well with the data for wire screens which covered a Reynolds number range of 3 to 1500.

Generalized Correlation

Using the experimentally determined values of the empirical constants, the dimensionless form of the correlation expressed in equation (16) may be written,

$$f = \frac{5.15}{Re} + \frac{0.51}{(Re)^{0.11}} \qquad (16)$$

where

$$= \frac{g_c \Delta P \epsilon^3}{LS\rho U^2} \qquad (13)$$

and

$$Re = \frac{\rho U}{\mu S}. \qquad (11)$$

Figure 8 shows a graph of equation (16) together with data points for the 14 screens over the entire velocity range from 0.1 to 30 f.p.s. The maximum deviation of the data from the curve representing equation (16) is $\pm 10\%$.

It was found by empirically introducing the pitch-diameter ratios into equation (16) that the correlation was improved somewhat to a maximum deviation of $\pm 6\%$. However, the variation in pitch-diameter ratio of 0.83 to 0.99 in this study was considered too small to warrant its inclusion in the correlation. Indeed, one of the reasons for the success of the correlation may be the relatively narrow range of porosities of from 0.61 to 0.68 because of the nature of wire construction. Work has been initiated to extend the range of screen variables and to minimize their possible interaction by using model screens of more precise defined and widely varied geometry.

There is some present evidence that very coarse screens with meshes less than about 30, do not follow the porous media model upon which the correlation is based. This is anticipated since very coarse screens would be expected to begin to approach the models based on flow past isolated cylinders in which the interaction of neighboring cylinders is relatively small.

The correlation defines the limiting Reynolds number below which purely viscous flow would occur. At a Reynolds number equal to unity, equation (16) shows that the viscous resistance amounts to about 90% of the total screen resistance. Thus, it would be expected, as found for flow through a wide variety of porous media, that a Reynolds number of about unity is the upper limit for maintaining viscous flow. As velocity increases to give a Reynolds number slightly greater than 100, the inertial resistance increases to 90% of the total screen resistance. At a Reynolds number slightly larger than 1000, the inertial resistance is 99% of the total resistance and the flow can be considered completely turbulent.

WIRE RESISTANCE IN THE SHEET-FORMING PROCESS

In the manufacture of pulp and paper, wire screens are used in sheet-forming, stock-thickening, and pulp-washing operations. Their chief function is to serve as a moving vehicle for drainage of water and simultaneous retention of fibers. On a paper machine, the wire plays an important role, at least in the initial and critical phase of sheet formation. For this reason, a brief examination of the sheet-forming process is deemed pertinent to the problem of wire resistance under study.

The removal of water from a fiber suspension through a wire screen to form a wet mat is deceptively simple in practice but difficult to analyze because of its complex nature. With a very dilute fiber suspension (less than about 0.02% consistency), the process can be quantitatively treated as filtration in which the fibers deposit

more or less freely on the wire. If the fibers and the wire do not interact, their resistances to flow of water are additive and may be measured separately. In the case of appreciable but constant interaction, the concept of an effective wire resistance can be incorporated in the filtration theory. This "effective" resistance is usually determined by suitable means of extrapolation from filtration data for a given combination of slurry and wire.

In the practical range of consistencies (0.1 to 1%), the fibers in a suspension form a loosely interconnected network. Upon removal of water from the suspension, the fiber network is compressed into a mat. Thus, sheet formation may be viewed more appropriately as a thickening rather than a filtration process, and requires a more elaborate theoretical treatment. In such a process, it is difficult, if not entirely unprofitable, to conceive a uniform fiber-wire interaction during initial drainage in which the wire is often the controlling factor.

There is as yet no direct evidence of a fiber-wire interaction. Its possible existence is deduced from considerations of the physical aspect of the phenomenon. As fibers are flexible, they can partly lodge in the wire meshes under fluid stresses. The presence of fibers within the screen structure reduces the openness and consequently increases the resistance to flow. The change in the wire resistance may, in turn, induce changes in the formation of the fiber mat. How far such interactions might extend or persist is an important question concerning sheet formation. Current work on flow through compressible fiber mats shows the same type of correlation applies as found for the wires in this study. This similarity facilitates studies of fiber-wire interaction which are presently proceeding.

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Electrostatic Coating Process for Making Flat Gummed Paper

F. W. HOLT, C. H. LORENZ, and R. B. REIF

The Brown-Bridge Mills, Inc., at Troy, Ohio, is now using a new dry-coating process to eliminate the use of volatile organic solvents in making flat gummed labels. Water-soluble adhesives and flexible binder material are applied in dry powder form by an electrostatic coating process. The laboratory and plant equipment developed in cooperation with Battelle Memorial Institute and Dilts Division of The Black-Clawson Co. represent the most advanced designs of the new coating equipment. A 60-in. coater and a complete installation for grinding coating powders are in operation at the plant. Further application of the new process in making other products is predicted.

The Brown-Bridge Mills, Inc., at Troy, Ohio, has made the first commercial application of the new dry electrostatic process for coating paper. The basic process was previously announced at the TAPPI Coating Conference in 1955.* At that time, the process described had been developed for the Bergstrom Paper Co., Neenah, Wis., for the production of clay-coated paper. The Brown-Bridge Mills, Inc., recognized the potentials offered by an electrostatic process for applying a noncurling coating of water-remoistenable adhesive to a web without the use of volatile organic solvents.

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* Reif, R. B., *Tappi* Vol. 38, No. 10: 607–609 (October, 1955).

When animal glue or dextrin is applied to a web from a water solution in the conventional manner, the dried film causes the web to curl. A process of cracking the dried adhesive film into microscopic particles, called "breaking," allows the web to lie flat within a useful range of relative humidity. However, the sheet will still curl to some extent whenever the relative humidity reaches either a low or high extreme.

In the electrostatic process, the remoistenable adhesive and binder are applied simultaneously as a powder and subsequently fixed to the web by activating the binder. No solvents are required. The coating produced in this fashion enables the web to lie perfectly flat over an extreme range of relative humidity. "Breaking" the adhesive film is not required.

From the conception of such a coating applied to a web by this process to a machine capable of commercial production has required more than 4 years of research. Formulation research and coating techniques were studied at Battelle Memorial Institute. Improved pilot-model coaters were constructed and evaluated before the commercial machine was erected at The Brown-Bridge Mills, Inc., by Dilts Division of The Black-Clawson Co.

THE BASIC PROCESS

The basic theory and operation of electrostatic coating was described in the article by Reif.* Briefly, the coating composition in powder form is suspended

Fig. 1. Bench-model coater

in an air stream, charged electrically, and deposited on the sheet by electrostatic forces. Charging the airborne powders is accomplished with unipolar discharge from a series of wires at a high electrical potential. The charged particles are then driven onto

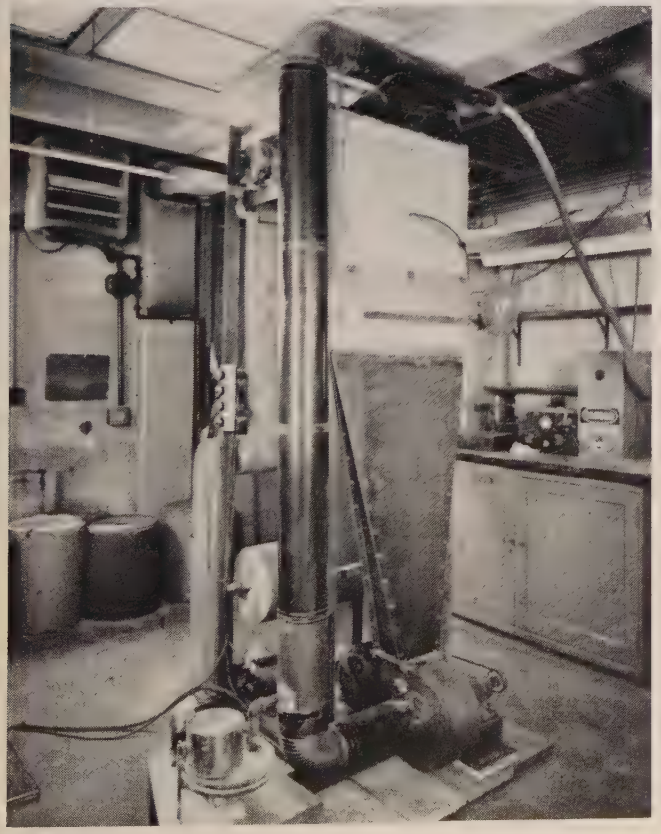

Fig. 2. Flat, electrode-type coater

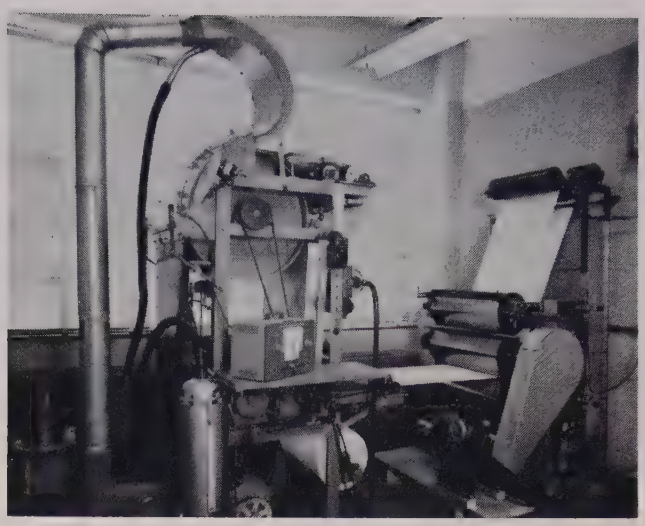

Fig. 3. Pilot model of drum-type coater

the paper by forces exerted by the electrical fields in the coater.

Coating weight is controlled by density of the powder cloud. Web speed is limited by the density of the cloud that can be generated and by the rate at which electrical charge can be drained off the powder layer deposited. The amount of charge on the powder layer limits the amount of coating that can be applied. Also, the charge must drain off before the web leaves the coater or charges on the powder and web cause disturbances in the coating that will mar the finish of the sheet.

LABORATORY EQUIPMENT

Laboratory Equipment

Figure 1 shows the bench-model coater that is used in the laboratory for making sheet samples of coatings. It operates on the same principle as the larger web machines. Sheets of paper to be coated are taped onto the grounded drum electrode. Coating material is blown up through the flat duct and out through a slot in the top of the duct which distributes the powder cloud across the surface of the drum. Wires under the shield at the top of the duct are at a high electrical potential. Emission from the wires charges the coating powder and the electrical field between the wires and drum drives the coating down onto the paper on the drum.

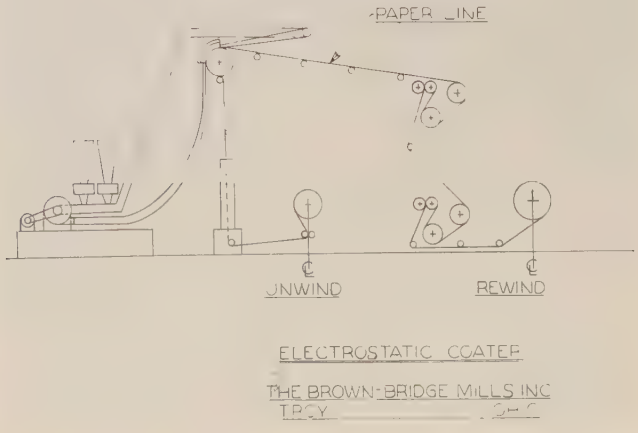

Fig. 4. Schematic of plant-model coater

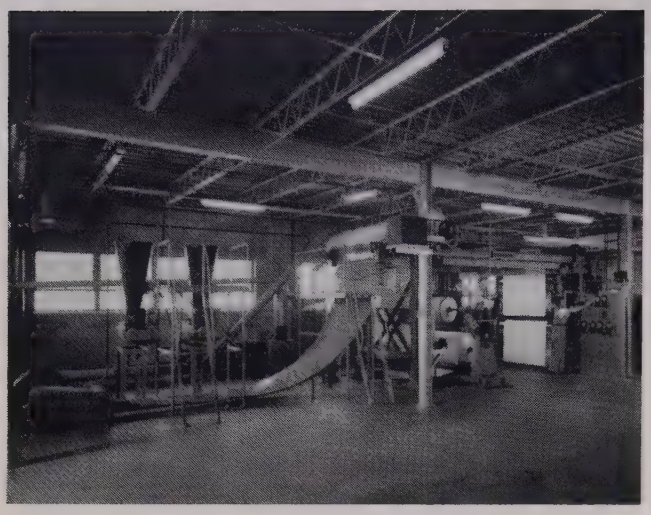

Fig. 5. Plant-model coater

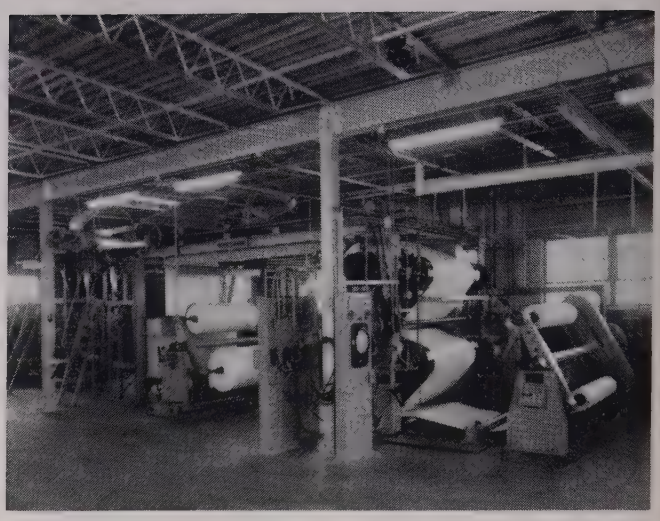

Fig. 7. Side view of coater

Pilot Equipment

Figure 2 is the old, flat, electrode-type coater, the first pilot model of the electrostatic coater described at the 1955 conference. Because of web-alignment problems and drag on the flat electrode, this design was not practical for a production unit.

Figure 3 shows the improved BB model of the pilot-coater used in making laboratory trials in coating webs. The unit coats webs up to 20 in. wide. The principal change from the older model is that the flat plate electrode was replaced by a rotating drum electrode as used on the bench-model coater in Fig. 1. As in the earlier models, the pilot coater consists of (1) a closed system for generating and circulating a cloud of coating powder, and (2) a coating chamber in which the coating powders are charged electrically and deposited on the paper. The paper web passes over the drum electrode.

The coating materials are fed into the circulation system upstream from the blower. Passing through the blower breaks up powder agglomerates and suspends the powder in the air stream.

As the coating powder is blown into the coating chamber, a part is deposited immediately, and the rest is returned to the blower and recycled. A vacuum attachment at the top of the machine removes sufficient air from the unit to produce negative pressure at the slit where the paper emerges from the coater. This prevents loss of powder from the coater.

The pilot-model coater is operated with a potential of 15 kv. and requires about 15 w. of power to deposit the coating. The charging wires are reciprocated and cleaned continuously during operation. The powder-cloud density which determines the coating weight is controlled by the rate of feeding the powder into the coater. To assure proper removal of electrical charge, the resistivity of the paper is controlled by conditioning the paper with steam or sprayed water before the coating is applied.

After the coating is deposited on the paper and leaves the coating chamber, it is fixed onto the paper by fusing the binder in the coating, chilling, and calendering. The fusing is generally done with heated rolls; however, exposure to solvent vapor in the tank on the far end of the machine can be used with some binders. Fusing by exposure to solvent vapors is rapid and requires much less solvent than is required in conventional solvent-solution-coating processes.

The pilot coaters were operated at speeds up to 100 f.p.m. Faster operation was not economical for laboratory trials.

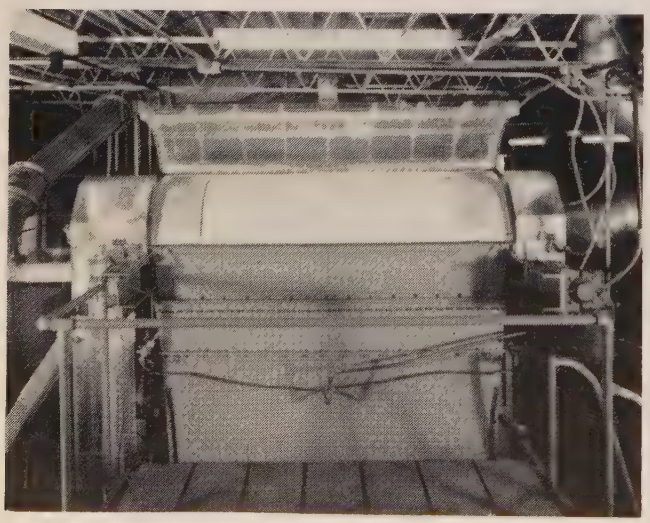

Fig. 6. Coating chamber

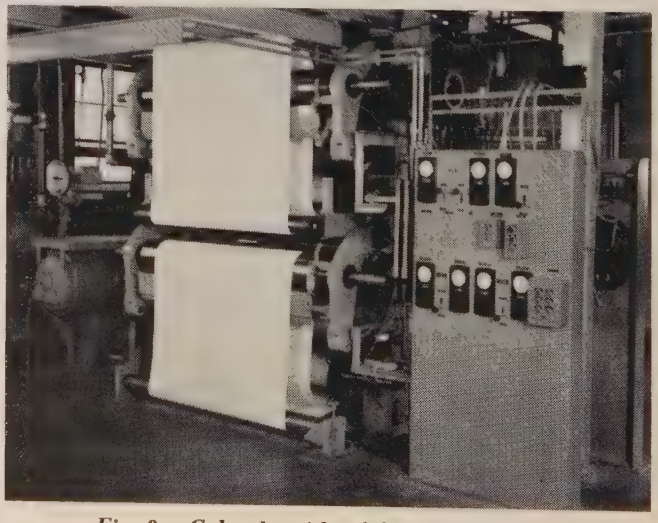

Fig. 8. Calender side of finishing section

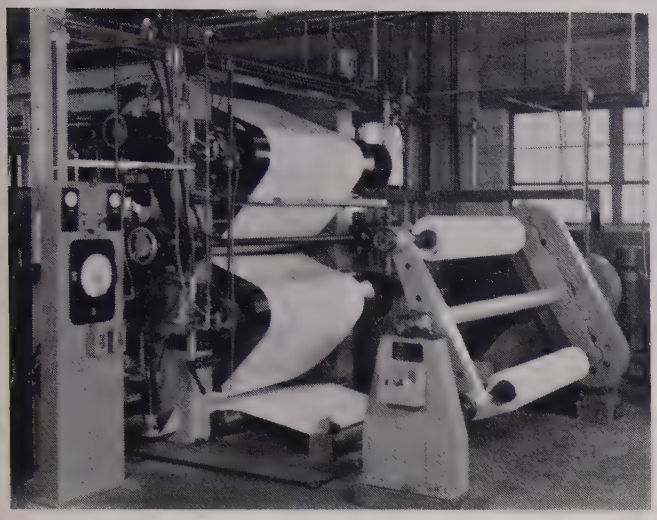

Fig. 9. Fusing and chilling rolls

Fig. 11. Grinding installation

Plant-Model Coater

The plant-model coater at Troy, Ohio, handles webs up to 60 in. It is designed to apply 15-lb. coatings (25 × 38—500) at speeds up to 300 f.p.m.

Figure 4 is a flow chart of the plant-model coater. It shows the path of the paper from the unwind through the conditioner, coater, finishing section, and rewind. Figure 5 shows the machine from the coater end. The powder circulation system, coating chamber, and powder feeders are located at this end. The powder feeders are weigh-belt type. Figure 6 shows details of the coating chamber with the plastic hood cover raised. The 0.010-in. wires produce corona for charging and depositing the powders. Insulating deckles along the edge of the drum are used with different width webs. Figure 7 shows the unwind and rewind end of the machine. Path of the paper to the conditioner and coating chamber is visible. Figures 8 and 9 show both sides of the finishing section including the calenders, gas-heated fusing rolls, chill rolls, and rewind.

ADHESIVES

The development of the dry-coating process by The Brown-Bridge Mills, Inc., was made for the production of gummed web material that will not curl over wide ranges of relative humidity. The water-remoistenable adhesive is applied as minute-sized particles bonded together and to the web by means of a relatively soft binder.

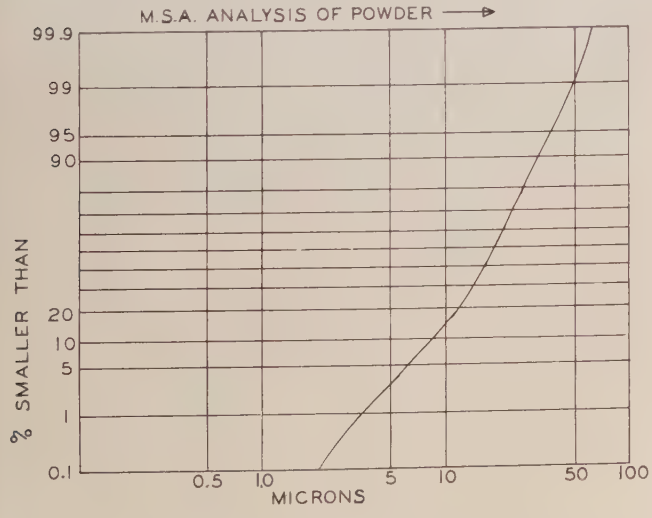

Fig. 10. MSA particle size analysis of typical coating powder

Figure 10 is an MSA particle size analysis of a typical coating composition. Practically all the material passes through a 325-mesh screen (44 μ). Some of the particles are as small as 1 and 2 μ.

The materials used in these compositions must be grindable, if not by themselves, at least when in mixture with the other ingredients of the coating.

The binder consists of a film-forming material and a suitable solid plasticizer. Under the action of heat, these materials fuse and form a permanently soft material.

GRINDING INSTALLATION

All of the powders for the electrostatic coating process are ground at The Brown-Bridge Mills, Inc., with a fine grinder capable of pulverizing the powders in the range of 1 to 50 μ.

Figure 11 shows the Brown-Bridge grinding plant. The pulverizer is water cooled, and precooled air is supplied to the grinder by an air conditioner. Powders are collected in a tube-type bag collector with a rotary lock delivery for the product. Prior to grinding, the coating materials are precrushed in a hammermill and blended together in a ribbon mixer.

POTENTIAL USES

Now that a production machine using this process is in operation, it may be that other uses for the process will develop. It is certainly possible that other types of coatings can be made to advantage by this method. It may be possible to eliminate dangerous or expensive solvents; to handle troublesome materials more easily, or in an improved form; to improve quality; or to provide coatings with characteristics not now available from those made by the customary methods. Patent applications on the process and equipment are pending.

We cannot predict what other coatings, if any, will be made by this process. We are hopeful, however, that this work will prove to be a useful step forward in the art of coating.

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Studies in the Gas and Vapor Permeability of Plastic Films and Coated Papers

Part VI. The Permeation of Water Vapor

A. W. MYERS, J. A. MEYER, C. E. ROGERS, V. STANNETT, and M. SZWARC

The permeability of a number of plastic films to water vapor has been investigated as a function of temperature and vapor pressure. Two general types of behavior were noted where the permeability constant is (a) dependent and (b) independent on vapor pressure. Both cases were investigated in some detail, the increase in the permeability constant as the temperature is lowered at a fixed vapor pressure, previously noted with organic vapors, was found in the pressure dependent systems. The sorption isotherms were measured by a quartz helix and by a tritiated water technique. Three pressure independent systems were obtained: polyethylene, polyethylene glycol terephthalate, and polypropylene. The sorption of water vapor was found to follow Henry's law, and the diffusion constants were calculated from the solubility coefficients and the permeability constants. They were found to be of a similar order of magnitude to the corresponding diffusion constants for oxygen, a molecule of comparable size.

THE mechanism of permeation of water vapor through polymer films is more complex than that of the permanent gases. In the case of hydrophilic films such as nylon or cellophane this is due to the sorbed water plasticizing the film leading to a diffusion constant, which increases with concentration. In these cases both the solubilities and the diffusivities increase as the relative humidity increases. In other films there appears to be a tendency for the sorbed water to associate into clusters, again leading to nonideal behavior.

Figure 1 shows a number of typical curves of the rate of water vapor transmission (Q) as a function of vapor pressure. The relatively hydrophobic films such as polyethylene and polyethylene glycol terephthalate (Mylar A) and rubber hydrochloride (Pliofilm NO) give linear plots indicating that the permeability constants are independent of pressure. Hydrophilic films such as the polyamides, on the other hand, give curves with slopes which increase to varying extents with vapor pressure, indicating that the permeability constants increase with vapor pressure. No other types of transmission–pressure curves have been reported. In this discussion the two types of behavior will be treated separately.

EXPERIMENTAL

The relevant characteristics of the various films studied are included in the appropriate tables.

The steady state permeation rates were determined by the high vacuum technique described in detail previously (*1*). The liquid-water measurements were made by distilling degassed water into the cell. Earlier measurements made by pouring water into the cell and leaving it exposed to the atmosphere were always too high because of dissolved air permeating with the water vapor.

It was not possible to measure the diffusion constants by the time-lag method in the case of water vapor because of errors introduced by adsorption of water onto the glass outlet side of the equipment. It was necessary, therefore, to measure the sorption isotherm directly and estimate the diffusion constant from the solubility coefficient and the permeability constant.

The sorption isotherms were measured directly using a quartz helix microbalance connected to a high vacuum and vapor system, as shown schematically in Fig. 2. The quartz helices used extended about 30 mm. for each 100 mg., and had a capacity of 0.5 g. Even with a high-precision cathetometer reading to 0.001 mm. it was not possible to measure sorptions less than about 0.05%. Since the values for poly-ethylene and polypropylene were considerably less than this it was decided to use tritiated water (HTO) for the measurements.

Water Vapor Sorption Isotherms Using Tritiated Water

Figure 3 shows a diagram of the experimental apparatus; a conventional high vacuum system was employed. The sorption system consisted essentially of a vapor reservoir, a test specimen which was suspended within a vertical glass tube (sorption chamber), and a pressure gage. This equipment was contained in a thermostated air bath which kept the temperature constant at 25±0.5°C. An exhaust system was attached to the air-bath enclosure to remove any radioactive material unavoidably let into the enclosure. The tritiated water-vapor source was prepared by diluting 1 g. of tritiated water (specific activity 100 mc./g., New England Nuclear Corp., Jamaica, N. Y.) to 10 cc. with distilled water. It was contained in a 25-cc. flask, as shown in Fig. 3, and was degassed by the standard freeze-thaw method.

The equilibrium vapor pressures were measured to ±0.1 mm. Hg with a Zimmerli gage connected to the sorption chamber. Extension rods were added to the controls of the gage to allow the measurement of vapor pressures from outside the enclosed apparatus.

The activity of the tritiated water was measured with a liquid scintillation counter (Packard Tri-carb Model 314) using a mixture of 1 liter of toluene (distilled over sodium), 6 g. of 2,5-diphenyloxazole (PPO), and 100 mg. of 1,4-bis(5-phenyl-2-oxazolyl-benzene (POPOP) as

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the scintillation liquid. The phosphors were scintillation grade (Pilot Chemical Co., Santa Fe Springs, Cal.). Tritiated toluene (New England Nuclear Corp.) was used as the primary standard.

The wash liquid consisted of a 50% solution of absolute ethanol and toluene (distilled over sodium). Ethanol was used since it exchanged rapidly with the tritiated water in the test specimen. Toluene was used, not only because of its excellent scintillator sol-

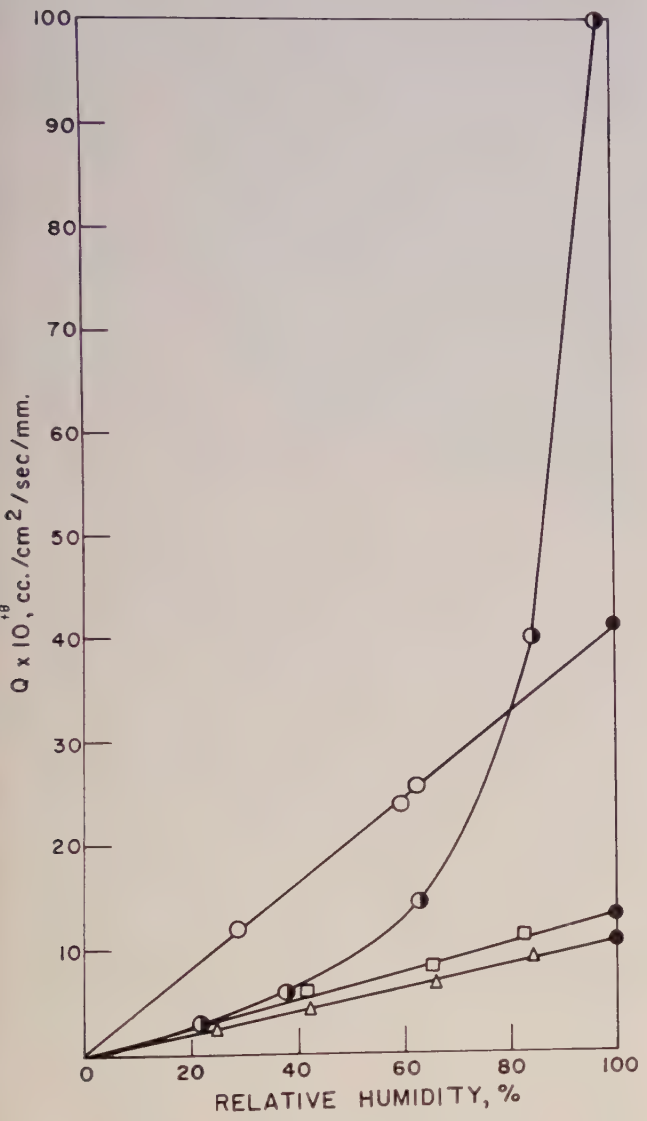
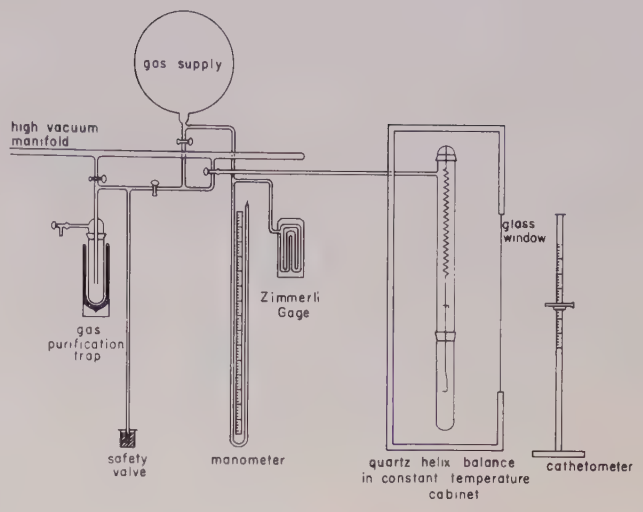


Fig. 1. Water vapor transmission as a function of humidity for various plastic films

● Liquid-water values. ◑ Nylon 6-6. ○ Mylar A100. □ Polyethylene density 0.922. △ Pliofilm NO.

vent properties, but in order to swell the test specimen to accelerate the tritiated water–ethanol exchange.

The polyethylene film (du Pont Co., Wilmington, Del.) was 0.065 in. thick and density of 0.923 g. per cc., and the polypropylene film (Monsanto Co., St. Louis, Mo.) was 0.10-in. thick and density of 0.906 g. per cc. Thick films are desirable because the exposed sample is necessarily exposed to the atmosphere for a few seconds, and during this time some sorbed moisture might be lost. The sorptions were measured at 25 ± 0.5°C. The system was degassed for 24 hr. (polyethylene) and 48 hr. (polypropylene) at room temperature and 10^{-5} mm. Hg. Tritiated water was then admitted until the desired pressure was reached. It was found that 24 hr. and 48 hr. for the polyethylene and polypropylene, respectively, were adequate times for equilibrium with the water vapor to be established.



SORPTION APPARATUS

Fig. 2. Sorption apparatus

At the completion of the sorption period, the final equilibrium pressure was recorded. Dry air was admitted slowly into the sorption chamber and the ground-glass cap with the sample attached was removed from the system. The sample was quickly immersed in 20 ml. of 50% toluene–ethanol solution contained in a test tube which was immediately stoppered with an aluminum-foil covered cork. (Removal procedure time was approximately 20 sec.) After the sample was removed from the sorption apparatus, the hood blower was turned on to exhaust to the atmosphere any radioactive material let into the enclosure during the sample removal.

The polyethylene was left in the solvent mixture for

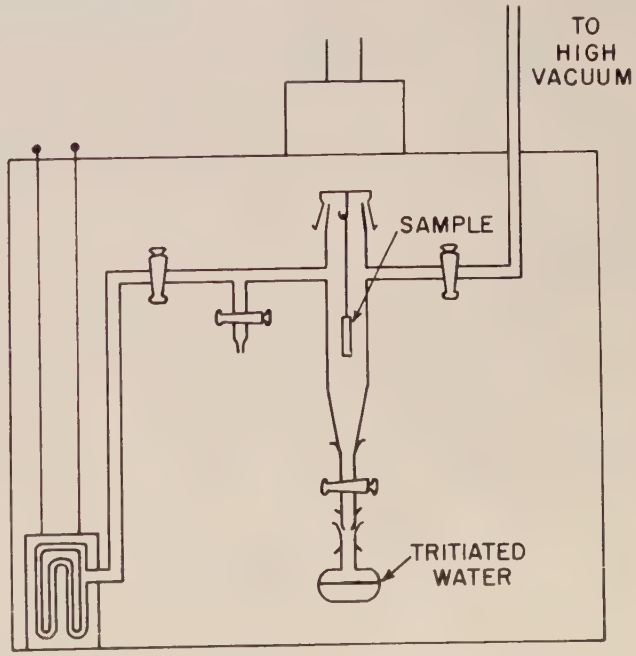


Fig. 3. Tritiated-water sorption chamber

Table I. Permeability of Plastic Films to Water Vapor 25°C.

Film	*Density, g./cc.*	*Permeability constant × 10^8, cc. S.T.P./ cm.²/sec./mm./ cm. Hg.*
Polyethylene	0.922	9.0
Polyethylene	0.938	2.5
Polyethylene	0.960	1.2
Polypropylene	0.907	5.1
Polyethylene glycol terephthalate (Mylar A)		13
Poyamide (nylon 6-6)[a]		7.0–68
Rubber hydrochloride (Pliofilm NO)		2.5
Polyvinylidene chloride (Saran)[b]		0.3–1.0
Cellulose acetate, unplasticized		550
Cellulose acetate and 15% dibutyl phthalate		740
Ethyl cellulose, plasticized		1300

[a] Dependent on relative humidity.
[b] Dependent on grade.

Table II. Temperature Dependance of Water-Vapor Permeability Constant

Film	*Density, g./cc.*	*P_0, cc./cm.²/sec./ mm./cm. Hg.*	*E_p, kcal./ mole*	*Temp. range, °C.*
Polyethylene	0.922	0.065	8.0	10–90
Polypropylene	0.907	1.2	10.1	10–90
Polyethylene glycol terephthalate (Mylar A)		4.2×10^{-7}	0.7	10–60
Rubber hydrochloride (Pliofilm NO)		0.013	7.9	20–60
Polyvinylidene chloride (Saran Q 517)		1.15	11.0	10–60
Cellulose acetate, unplasticized		7.1×10^{-6}	~0	10–60
Cellulose acetate and 15% dibutyl phthalate		7.1×10^{-6}	~0	10–60
Ethyl cellulose (Ethocel 610)		1.1×10^{-5}	~0	10–75

12 to 16 hr. at room temperature, whereas the polypropylene was washed at 70°C. The samples of film were then raised with tweezers above the solution in the test tube and washed with an additional 10 ml. of the solution from a volumetric pipet. The sample of film was deposited into a second test tube containing 20 ml. of the 50% toluene–ethanol solution and the above procedure repeated. A series of four washings were used to ensure complete removal of HTO from the sample film. The total time of washing for each test specimen was approximately 48 hr.

Aliquots (2. cc.) were pipetted from the wash solutions and counted for each of the washings, and the tritiated water content of the original sample calculated. The final isotherms obtained in this way are shown in Figs. 8 and 9. Both polymers showed considerable exchange with the tritium as shown by the residual activity of the film after completely degassing the sample for several days. The activities due to exchange have been subtracted from the observed activity in calculating the data used in plotting the isotherms shown in Figs. 8 and 9. This problem as well as other features of the tritiated water method are being explored further and will be reported in due course.

RESULTS AND DISCUSSION

Table I gives the water-vapor permeability constants

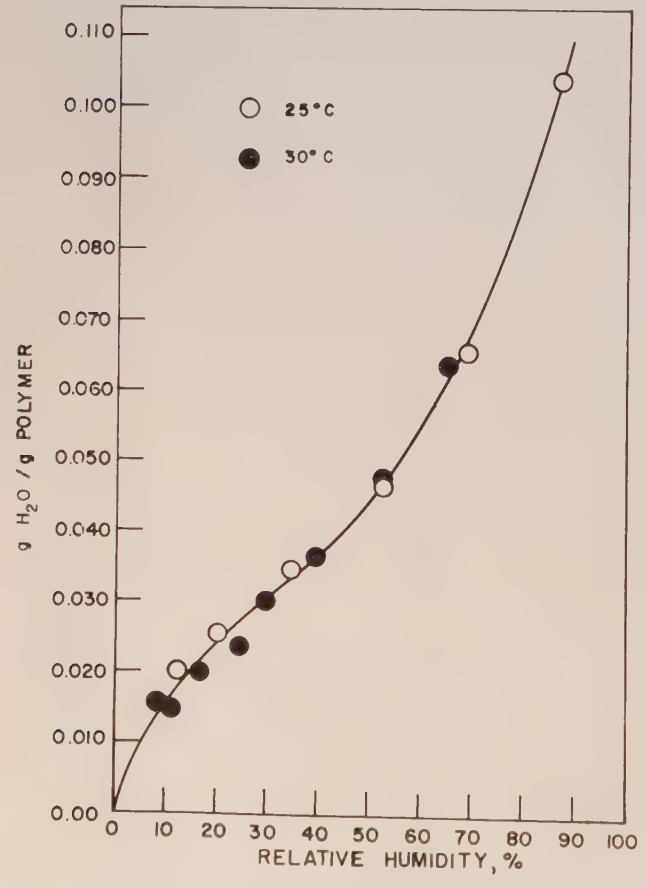


Fig. 4. Sorption of water by nylon 6-6 as a function of relative humidity

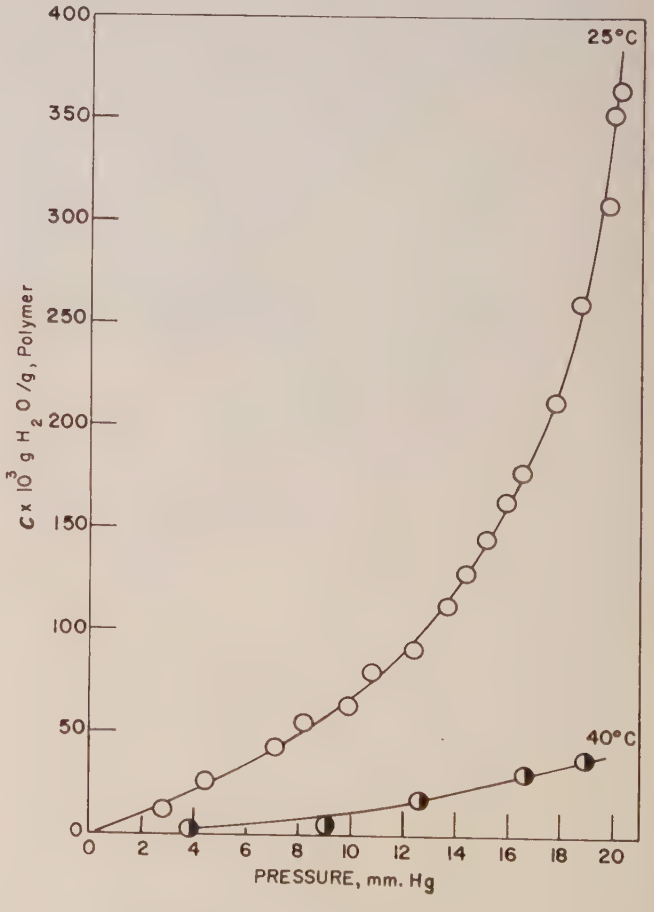


Fig. 5. Sorption of water vapor by polyvinyl alcohol as a function of vapor pressure

for a number of different polymer films. (The values for polyethylene were inadvertently omitted from our previous paper (*2*). Except for the polyamide (nylon) films, all the constants were found to be essentially independant of the relative humidity. Consequently, the value for liquid water should be the same as for the water vapor if calculated using the vapor pressure of liquid water at the temperature of measurement. Figure 1 shows that this is indeed true in most cases (*3*, *4*) the solid circles representing the liquid water values. Some polymers, such as ethyl cellulose, showed small increases in the permeability constants at very high relative humidities (*5*).

The temperature dependence of the permeability constants for the pressure-independent cases obey the normal Arrhenius relationship:

$$P = P_0 \exp. (-E_p/ET)$$

where

P = permeability constant cc./cm.²/sec./mm./ cm. Hg
P_0 = pre-exponential factor, cc./cm.²/sec./mm./cm. Hg
E_p = activation energy for the overall permeation process, kcal./mole

The values for E_p and P_0 are given in Table II together with the temperature range over which those values were measured. The values for E_p are considerably smaller than for the permanent gases of similar molecular size, such as oxygen. This is due to the large negative value of the heat of solution in the case of water vapor, since:

$$E_p = E_d + \Delta H$$

where

E_d = activation energy for diffusion, kcal./mole
ΔH = heat of solution, kcal./mole

The heat of solution ΔH (*6*) is equal to the sum of the heat of condensation $\Delta H_{cond.}$ and the heat of mixing, ΔH_m, and is close to zero for the gases. In the case of water vapor, however, the former is -10.5 and the latter is about 5 kcal./mole or less (*7*). Consequently, one should add about 5.5 kcal. to E_p to obtain E_d for water vapor. When this is done, the values are of the same order of magnitude as for oxygen.

The dependence of the permeability constant on pressure will now be considered. For convenience the discussion will be divided into pressure-dependent and pressure-independent systems.

Pressure-Dependent Systems

All the examples reported refer to films which swell in water, such as cellulose, polyamide and polyvinyl alcohol. In some ways the behavior of these systems parallels the situation found with organic vapors and various polymers. The permeability constant may be defined as the product of the diffusion constant D and the solubility coefficient S, and it is necessary to know the effect of vapor pressure on both these quantities. The effect of pressure on the solubility may best be shown by means of the sorption isotherms, Figures 4 & 5 give the isotherms for polyamide (nylon 6–6) and polyvinyl alcohol. It is clear that in the case of nylon the heat of mixing is small since the points for the two temperatures nearly coincide; it should be noted that the polyvinyl curve is plotted as a function of pressure and not relative humidity, thus showing a much greater effect of temperature. The shape of the curve for nylon is typical for a polymer having strong hydrogen bonding sites. after these are occupied a more random mixing process occurs. The sorbed water effectively plasticizes the film and thus facilitates the diffusion process, i.e., the diffusion constant increases with increasing water in the film. Since both the solubility and the diffusivity increase, the net effect is a considerable increase in the permeability constant with pressure, as indicated in Fig. 1. In the case of nylon 6-10, which absorbs much less water, the diffusion constant does not appear (*8*) to change with concentration up to about 65% R.H., although it probably does begin to increase at higher humidities.

The behavior of polyvinyl alcohol is more striking,

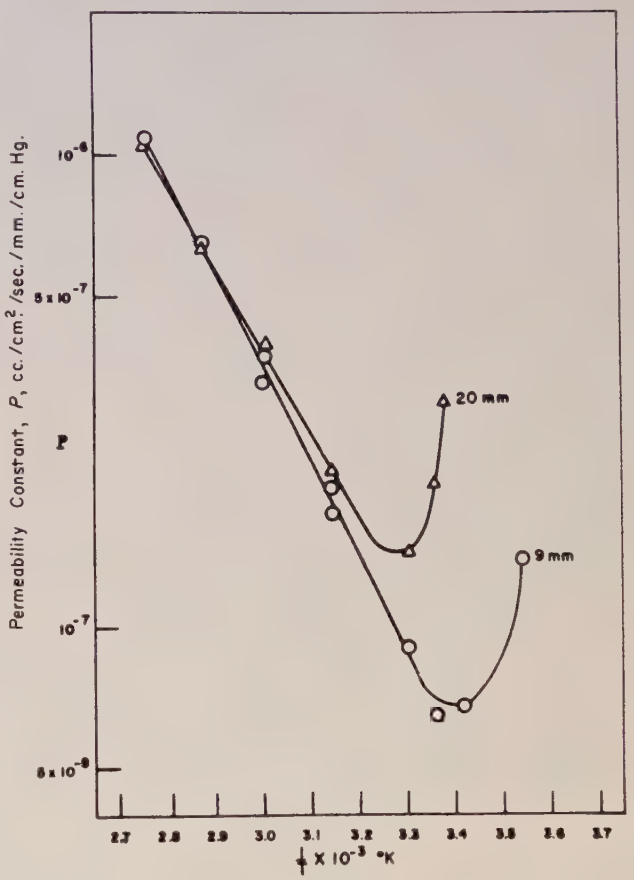


Fig. 6. Temperature dependence of the permeability constant for water in nylon 6-6 at vapor pressures of 9 and 20 mm. Hg

the sorption isotherm resembles that of an organic-vapor isotherm, such as hexane in polyethylene. However, the film studied was plasticized and the initial bonding sites were probably already occupied by plasticizer molecules. The unplasticized film, however, also showed this type of isotherm and perhaps deserves further study since, apparently, random mixing occurs with this system. The rapid increase in the solubility with vapor pressure and the high degree of swelling leads also to the diffusion constant D increasing tenfold between 7 and 20% R.H. (*8*). Similar large increases in the diffusion constant have also been noted in the case of cellulose (*9*).

The dependence of the permeability constant on temperature at a fixed vapor pressure for these systems

is interesting, and the plots for nylon at two vapor pressures is given in Fig. 6. The phenomenon of the permeability constant beginning to increase as the temperature is lowered has already been noted with organic vapors and has been discussed in detail (*10*). As the temperature is lowered at fixed vapor pressure the relative humidity increases leading to greatly increased solubility (see, for example, Figs. 4 and 5). The increased concentration of water increases the diffusion constant and overcoming, to varying extent, its decrease due to the lowered temperature. Table

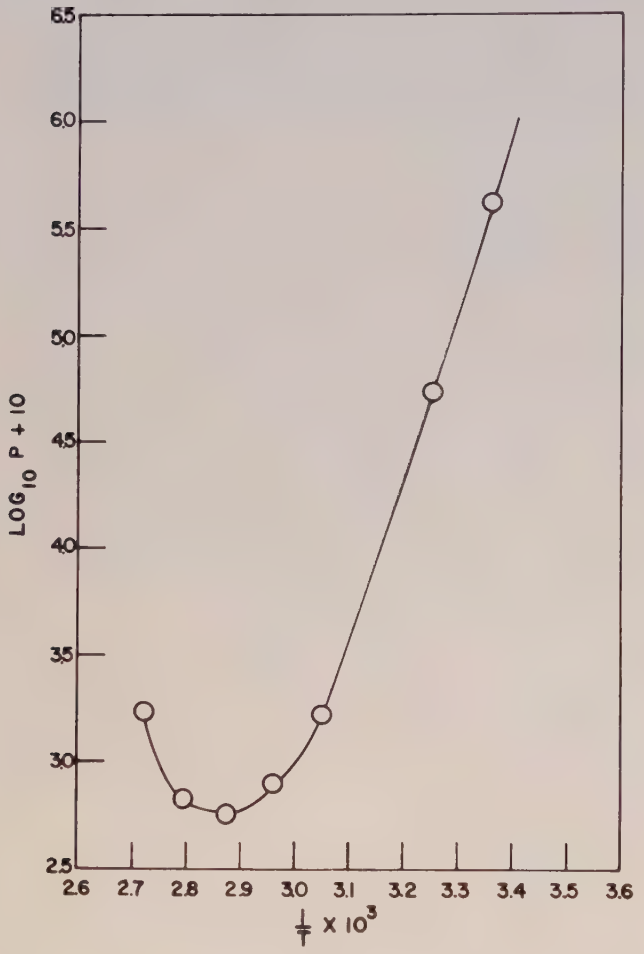


Fig. 7. Temperature dependence of the permeability constant for water in polyvinyl alcohol at a pressure of approx. 23 mm. Hg

III gives the actual values of D, S, and P at the point of inflexion of the log (permeability constant–reciprocal temperature) plot, and illustrate these effects clearly although only a 5°C. temperature change is involved. Figure 7 shows the striking behavior of polyvinyl alcohol. On decreasing the temperature from 40° to 25°C., for example, the permeability constant increases more than twenty-fold. This is due to increases in both the solubility (ninefold) and the diffusion constant (2.5 times) as the temperature is lowered.

Films with Pressure-Independent Permeability Constants

Most polymer films have permeability constants for water vapor which are essentially independent of the relative humidity. At first sight this might not appear unusual since the concentration of water vapor in the films is often quite low even at high humidities, and it would seem reasonable that Henry's law would be obeyed and that the diffusion constant would be independent of concentration. However, two pieces of evidence indicate that the situation is more complex. In the case of the simple gases it has been established (*6*) that the ratio of the permeability constants is approximately constant for a large number of polymer films, whereas if one considers the ratio for water vapor and nitrogen it can be seen (Table IV) that tremendous

Table III. Effect of Temperature on *P*, *D*, and *S* of Water Vapor in Nylon

Temperature, °C.	*Water vapor pressure, mm. Hg.*	*Relative vapor pressure, %*	*Sorbed water content, % by wt.*	*S, cc. S.T.P./ cc./atm.*	*D × 10¹⁰, cm.²/sec.*	*P × 10⁷, cc./cm.²/ sec./mm./ cm./Hg.*
30	9	28.3	2.8	3420	2.3	0.91
25	9	37.8	3.5	4330	1.2	0.65
30	20	62.9	5.7	3230	3.6	1.45
25	20	83.9	8.6	5150	2.7	2.03

differences exist. Secondly, where the diffusivities and solubilities have been separately determined it has been reported (*11*, *12*) that S increases with pressure and D decreases with concentration and that the two effects exactly compensate each other leading to a pressure-independent permeability constant.

The first case of this kind was reported by Rouse (*11*) for polyethylene; however, the water-vapor sorption figures obtained were far higher than all those reported or expected by analogy with liquid hydrocarbons. More recently McCall, Ambrose, and Lanza (*13*) re-

Table IV. Permeability to Nitrogen and Water Vapor at 30°C.

	Density, g./cc.	*P × 10⁹, cc./cm.²/sec./ mm./cm. Hg.* N_2	H_2O	*Ratio* $\frac{H_2O}{N_2}$
Poly(chlorotrifluoroethylene) (Kel F)	...	0.0035	0.29	83
Polyvinylidene chloride (Saran)	...	0.001–0.0015	1.4–10.0	1400–6700
Polyethylene	0.954	0.33	18	54
Rubber hydrochloride (Pliofilm NO)	...	0.008	25	3,150
Polypropylene	0.907	0.44	68	155
Polyethylene	0.922	2.0	80	40
Polyethylene glycol terephthalate (Mylar A)	...	0.005	130	26,000
Polyamide (nylon, ~90% R.H.)	...	0.02	700	35,000
Cellulose acetate, plasticized	...	0.28	7,500	26,800
Ethyl cellulose, plasticized	...	8.4	13,000	1,540

determined the solubility directly using a deflection balance. It was found that in normal polyethylene (density 0.922 g./cc.) the solubility was less than 0.005%; much smaller than had been previously reported. A highly oxidized sample did absorb 0.011%, however, this is still below the values reported earlier. We decided, therefore, to re-measure the solubility directly using the tritiated-water technique described in detail in the experimental section. The water-vapor isotherm obtained in this manner is given in Fig. 8. In spite of the considerable scatter it is possible to say

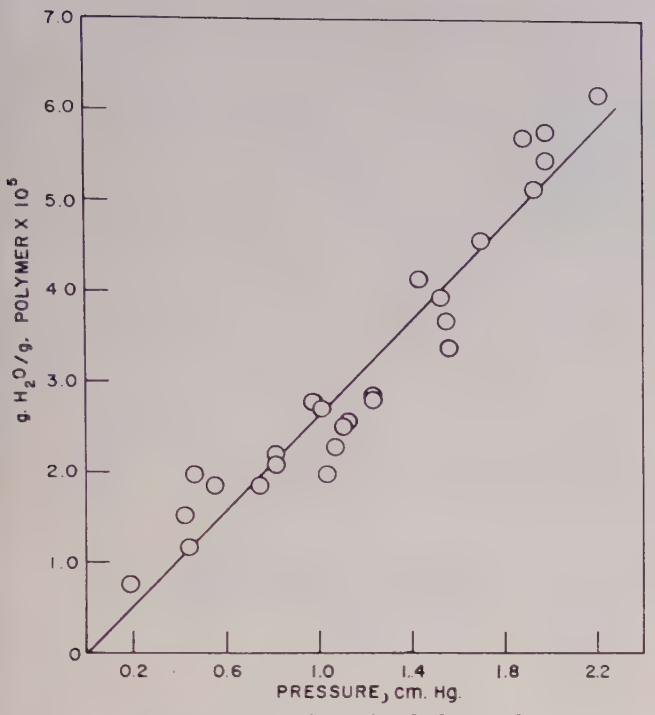


Fig. 8. Sorption of water by polyethylene; density 0.923 g./cc. at 25°C.

that little, if any, increase in the solubility coefficient with vapor pressure takes place. The solubility of water at 25°C. was found to be 0.0062 ± 0.0013% by weight. This figure is in good agreement with the estimate of Klute (*14*) and with the maximum value of McCall (*13*), particularly since the exchange values indicated that some oxidation of the samples had occurred. Since the isotherm is linear the diffusion constant for water in polyethylene at 25°C. can now be calculated from the solubility and the permeability it was found to be 2.9×10^{-7} sq. cm. per sec. This compares with the estimate of McCall of 1.5×10^{-7} and

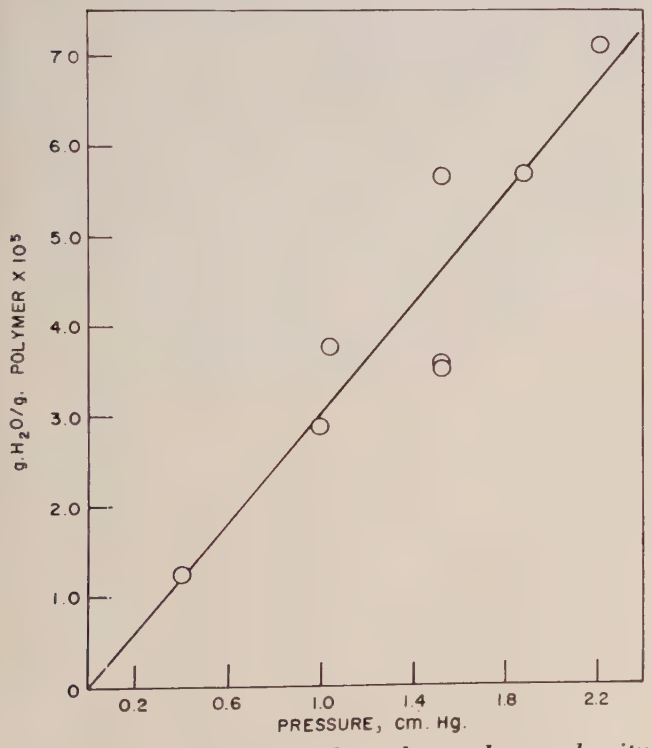


Fig. 9. Sorption of water by polypropylene; density 0.906 g./cc. at 25°C.

with the value for oxygen (a molecule of similar size) of 3.4×10^{-7}. It would seem that the early work of Rouse was in error, possibly due to use of an impure sample of polyethylene, and that the sorption does follow Henry's law as suggested previously by the data of Cutler and McLaren (*15*) and recently by Klute (*14*). The interesting problem remains as to whether the increase in water solubility with oxidation affects also the permeability constant, and this is worthy of future study.

Figure 9 shows the isotherm for polypropylene. Again a linear isotherm was obtained showing a solubility of 0.0072 ± 0.0015%. This value leads to a value for the diffusion constant of 1.5×10^{-7} compared with 1.35×10^{-7} for oxygen.

Figure 10 shows the sorption of water by polyethylene

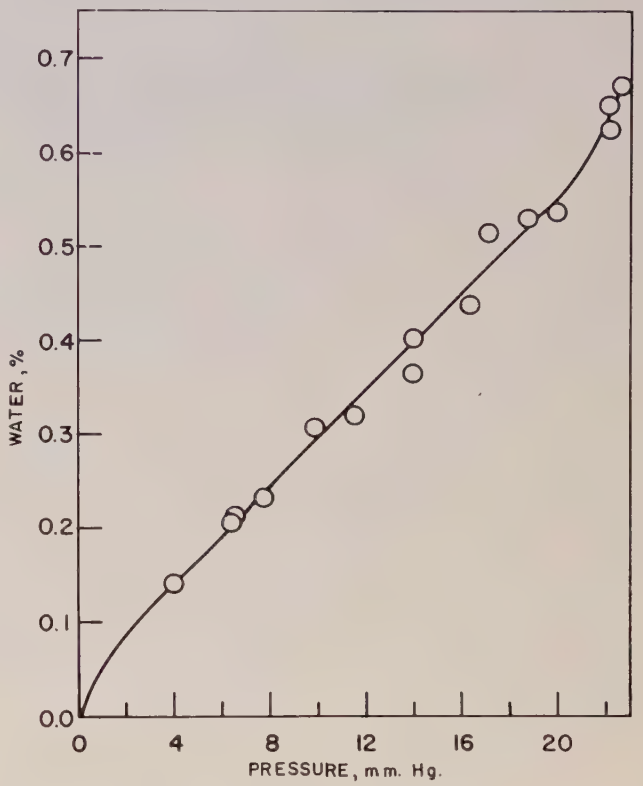


Fig. 10. Sorption of water vapor by Mylar A 100 25°C.

glycol terephthalate (Mylar A). The isotherm is nearly linear but shows some evidence of an S-shaped curve. The initial shape of the curve could be due to hydrogen bonding of water, e.g., to the end-groups of the polymer. The small increase at very high humidities could account for the slightly larger permeability constants sometimes found with liquid water compared with the unsaturated vapor (*3*). Assuming linearity the mean solubility coefficient can be determined from Fig. 10 and, combined with the permeability constant, the diffusion constant can be calculated. This leads to a value of 5.6×10^{-9} sq. cm. per sec., which is similar to the measured value for oxygen of about 4.0×10^{-9}.

It can be seen that for the three polymers studied, i.e., polyethylene, polypropylene, and polyethylene glycol terephthalate the diffusion constants are normal because they are similar to those found for the similarly sized oxygen molecule. The tremendous difference between the water and gas permeabilities of the polyolefins and of polyester is, therefore, due to the greater

solubility of water in the more polar polyester film. The concentration of water in the film is not, however, great enough to lead to any noticeable increase in the diffusion constant with concentration or to an increase in gas permeability with relative humidity (*16*).

Other polymer-water systems are presently under study and will be reported elsewhere.

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We would like to thank Mr. V. Tammela who carried out a number of the permeability measurements reported in this paper. Also Drs. Bixler and Micaels of M.I.T. for the oxygen diffusion constants.

Convenient Projector for Fiber Measurements

JAMES D'A. CLARK

A simple and inexpensive apparatus is described to project 25.4:1 magnified images of fibers on a grid outlined by stretched threads, fastened to the underside of a frosted plate glass screen which is set flush in a table top. Occupancy of usable working space and heating of the room by the projection lamp are avoided.

The projection of the images of fibers mounted on a slide, either downward or horizontally on to an opaque screen, has the disadvantage of shadows being cast while measurements are being made. More recently several different pieces of equipment have become available which project enlarged images of the fiber slide to the underside of a horizontal or sloped ground glass screen. The bulkiness of the apparatus and, sometimes, its unsuitable magnification or cost, are drawbacks.

Figure 1 is a diagram of a homemade projector which has proved very satisfactory. The main equipment, 10, conveniently part of a 35-mm. photographic enlarger, is mounted outside of a darkroom or, for example, the constant humidity room. Access to the slides is through the hinged or sliding door, 11. The rays from the projector are turned into the room beneath the bench top, 12, by the prism, 13. The mirror 14, is a polished, chromium-plated, rolled-brass plate about $^1/_8$ in. thick, 12 by 17 in., and is mounted immediately beneath the bench; it serves to turn the rays upward. The screen, 15, consists of a 12 by 12-in. piece of plate glass whose upper surface has been ground. Its lower surface carries an 8 by 8 in. (or larger) grid of 1-in. squares made by spacing a number of long threads 1 in. apart and fastening the end of each thread to the glass with adhesive tape. The sharp, thin shadows cast by the threads make a very satisfactory figure, for use in such methods as TAPPI Standard T 232 sm—Fiber length of Pulp by Projection—or T 234 sm—Coarseness of Fibers by Projection.

Because the plate 14 is so near the screen, slight imperfections of the flatness of its polished surface have no appreciable effect on the images so that a plated, ordinary rolled brass plate is satisfactory. It is perhaps a lack of realization that there is no need for a large and expensive single-surface mirror, that has discouraged the general use of this design in the past.

The magnification of the projector and the distance of the lens from the screen are predetermined by experiment and are conveniently arranged to give a magnification of 25.4:1 so that 1 mm. on the slide equals 1 in. on the screen. By making the height of the projector adjustable over a few inches this can be accurately set.

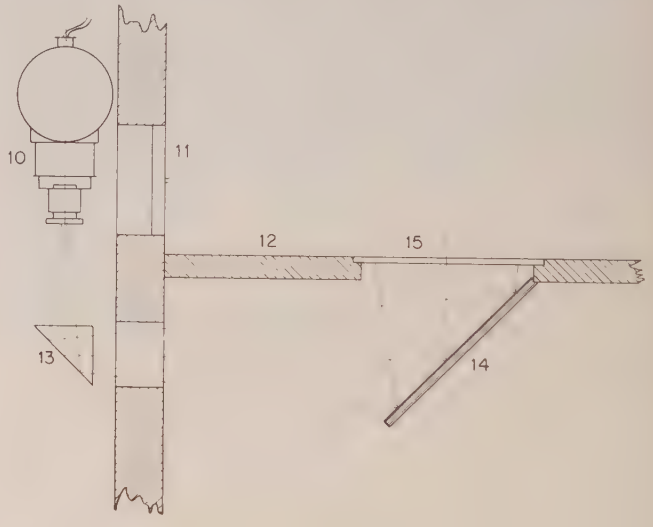

Fig. 1. Diagram of projection apparatus

Because the top of the screen is flush with the bench top, when not in use, it becomes part of it. The space immediately beneath the bench top is seldom used so that the equipment takes up no useful space in the room. The placing of the projector outside avoids not only any stray light but also the considerable heat given off by the projector lamp.

James d'A. Clark, Oregon State College, Corvallis, Ore.

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The Effects of Outside Storage on Slash Pine Chips in the South

C. W. ROTHROCK, JR., W. R. SMITH, and R. M. LINDGREN

Potential advantages to be gained in outside storage of wood chips include better wood measurement, lower handling costs, stabilized chipping and woodyard operation and solution of storage problems arising from increased use of sawmill residues, mixed species, and establishment of chip mills at the wood source. A test pile, containing 106 units of slash pine chips, was constructed in June, 1959, at Fargo, Ga. Monthly samples were collected for moisture and specific gravity determinations and for identification of decay organisms. Samples were also collected for pulping evaluations. Temperatures within the pile increased as much as 60°F. in the first weeks and remained above ambient levels. A drying cycle in the pile was followed by an increase in moisture to an abnormal level. Dark staining of the chips became evident after two months' storage and was prevalent in about half the chips after 5 months. Dark-stained wood showed a type of fungus attack known as soft-rot. Specific gravity losses amounted to 1–1.5% per month, no greater than observed losses on roundwood. There was no loss in percentage yield nor change in permanganate number with storage time but the per cent rejects decreased. Loss in pulp tear strength amounted to about 5% per month, comparable to roundwood. The results indicate that outside storage of chips in the south is feasible.

Outside storage of wood chips has been a subject of increasing interest to the paper industry in the South. Potential advantages to be gained from chip storage include:

1. Wood chips, as contrasted to pulpwood, are more easily measured (volume, moisture sampling, etc.,) and measurements are more reliable. The mills can obtain a better knowledge of what has been received and what is on hand, and it is easier to judge the efficiency of the pulping processes.
2. Handling of chips presents possibilities for savings in yard labor.
3. Adequate chip storage allows woodyard and chipping operations to be stabilized independently of variations in pulp production, with consequent savings in crew coverage and overtime.

Interest in chip storage is intensified by other trends and developments, depending on local circumstances. These include:

1. Increasing utilization of residue chips from sawmills and veneer mills.
2. Establishment of chip stations close to the source of wood, the advantages of which have been demonstrated at Fargo, Ga. These flows of chips from outside sources can create handling and storage problems at the pulp mills.
3. In developing the utilization of hardwoods, levels may not have been reached where a separate full-time operation is feasible, but levels may have been reached where frequent intermittent production is required, creating problems in receiving, storing, and using two kinds of wood.

The practice of storing chips in large outdoor piles is quite general on the west coast, and if there is any deterioration of stored chips, the mills do not seem to be concerned about it. In the south, it has been demonstrated that pulpwood in storage deteriorates unless submerged in water. Concern over possible deterioration of chips has deterred outside chip storage in the south. The literature survey which follows shows that the effects of storage on rough pulpwood in the south are well understood; but that knowledge is sketchy on the effects of storage on wood chips. Most of the small amount of published information is opinion inadequately supported by data.

This report covers the first of a series of studies on chip storage and is believed to be the first report based on a carefully planned program and supported by exhaustive test data.

LITERATURE SURVEY

Pulpwood Storage

Keaton and Gillespie (*1*) reported a study of dry, infected pulpwood stored for an unknown period of time at Bogalusa, La. Yield from the old wood was 3.3% lower than yield from freshly cut wood, tear was 25%, tensile 12%, and burst 15% lower.

McGovern, Martin, and Hyttinen (*2*) reported a study of slash pine cut in October and stored at Bogalusa, La. Observed changes were:

Months in storage	*Variation, %*			
	Wood density	*Tear*	*Tensile*	*Burst*
4 (Winter)	−2.6	0	+7	0
6	−5.8	−10	+9	0
9	−10.0	−12	0	−15
12	−16.2	−24	−3	−11

Under constant cooking conditions, pulp permanganate number increased from about 24 to about 26, i.e., alkali requirements increased. Percentage yield of pulp, based on weight of wood, was unchanged. The main agency of decay was the fungus *Peniophora gigantea*, which attacks both lignin and carbohydrate.

Lindgren (*3*) summarized the preceding reference and reported changes in wood density as follows:

Months in storage	*Wood density variation, %*	
	Summer	*Winter*
2	−2	0 to −1.5
4	−6 to −8	−1.5 to −3
6	−8 to −10	−3 to −5
12	−11 to −15	

C. W. Rothrock, Jr., Regional Supervisor of Pulping Development, St. Regis Paper Company, Pensacola, Fla. W. R. Smith, Chief of Forest Utilization Research, Southeastern Forest Experiment Station, Asheville, N. C. R. M. Lindgren, Chief of the Division of Wood Preservation Forest Products Laboratory, Madison, Wis.

No major differences were observed among southern pine species.

In addition to the *Peniophora* fungus mentioned previously, Lindgren stated that *Lenzites saepiaria*, a cellulose destroying fungus, became prevalent after six months, leading to losses in percentage yield as well as losses in wood density. A green mold, *Trichoderma*, was described as having no adverse effects on the wood, but apparently inhibiting the growth of other organisms and increasing the water permeability of the wood.

Perkins (*4*) reported tests at Jacksonville, Fla., showing about 8% loss in wood substance during eight-months' storage, starting in June. Percentage of total pulp yield, based on wood weight, was unchanged but reject rates increased with storage time. Tearing strength was reduced progressively reaching a loss of 28% after 8 months. Seventeen per cent loss in burst occurred early (40 days) but burst did not deteriorate with further storage. Tensile was not affected.

Chesley, Hair, and Swartz (*5*), in comparing yard storage with underwater storage, reported that pulpwood stored for six months on the yard, beginning in June, lost 7% in wood density and that the percentage yield was reduced by an additional 6%. Tear was reduced about 25% and burst was reduced about 25%.

Ference and Gilles (*6*) reported work at Brunswick, Ga., which appears to be the most exhaustive published study of pulpwood storage. Wood density and moisture data are used for comparison in a later portion of this report. Six months of storage, beginning in June, resulted in 8.4% loss of wood density. There was no change in percentage yield, an increase in alkali demand, and an increase in rejects. No control tests were reported, but loss in tear between one month and six-months' storage was about 16%, suggesting that overall loss in six months approached 20%. Tensile and burst were not affected.

Peniophora gigantea was identified as the main agency of decay, in association with *Schizophyllem commune*.

Baker (*7*) reported yield losses on longleaf pine:

Months in storage	*Yield loss, %*	
	Summer	*Winter*
2	4	1
3	5	2.5
6	9	7

In the discussion following the report by Baker (*7*), it was stated that losses in summer storage at Charleston, S. C., averaged 8.5% and ran as high as 15 to 18%. Winter losses averaged 4%.

Chip Storage

A late 1957 report by Gustafson (*8*) contains the earliest known published results of chip storage in the south. In South Carolina, two- to three-cord piles were held for 2, 10, and 18 months. In 10 months, wood density loss was small and percentage yield was unchanged. Decay was evident after 18 months.

A large 50-ton pile was held for 12 months. Moisture increased to 60%, except in the center of the pile. Percentage yield was unchanged, but rejects were doubled. Tear was reduced by 15 to 35%, burst was reduced by 15 to 18%, tensile was not affected.

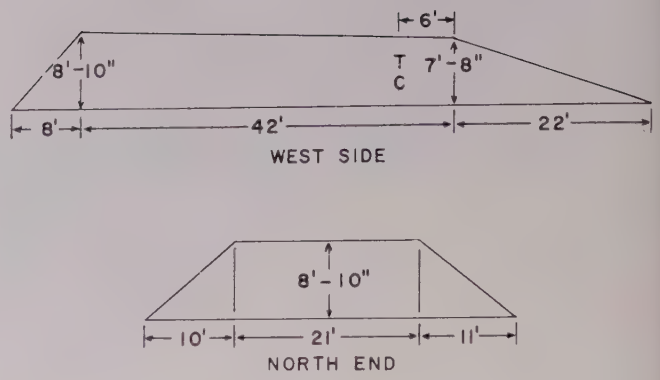

Fig. 1 Chip pile

Holekamp (*9*) reported tests in 1958 at St. Mary's, Ga., on one carload of chips stored for 4 months. Basket cooks in mill digesters failed to produce reliable indications. Holekamp further reported on a large pile at Evadale, Tex., which appeared to be in good condition after three summer months. Pulping tests showed no change in yield or pulp qualities during four-months' storage. Wood density was not reported.

Heathcock (*11*) reported tests on 350 tons of chips stored in Texas for 6 months, beginning in July. This and preceding progress reports were summarized by Holekamp (*10*). Temperature in the pile rose as high as 114°F., then gradually declined. Moisture increased to about 60%. Wood density was reduced about 5% during six months' storage, tear was reduced by 6 to 9% during five months' storage, burst decreased by 3 to 4%. No yield data were reported.

After four months, the sap stain fungus *Ceratocystis piliferum* and *Trichoderma* and *Penicillium* molds were identified, but no mention is made of rot-producing fungi.

PROCEDURE

Establishment of Test Pile

The test pile was built in May 28 and 29, 1959, at the St. Regis chip station in Fargo, Ga., in the presence of representatives of the U. S. Forest Service, St. Regis Forestry Department, Woodlands Division, and Technical Division. An area 100 by 50 ft. had been graded, covered with 6 in. of lime rock and topped with 1.5 in. of asphalt. Chips from freshly cut trees were placed on the area with a dump truck. Fifty-nine loads were used to build a pile containing approximately 106 units of slash pine chips. Chips were distributed on the pile and the pile compacted with a D-2 Caterpillar tractor.

Figure 1 shows the general shape and dimensions of the chip pile. Copper-constantan thermocouples were placed in 12 positions across the pile and 6 ft. in from the top of the slope at one end of the pile. Leads from

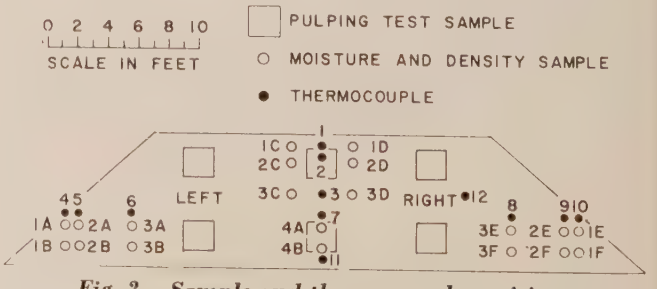

Fig. 2. Sample and thermocouple positions

the thermocouples were tagged and the potentiometer calibrated. Figure 2 shows the position of the thermocouples. The Forest Service established a weather station for reporting temperature, rainfall, and wind velocity.

Sampling

To establish base-line data, a 1-gal. sample was taken from every second truck load for Forest Service tests of moisture and specific gravity. Two large scoops of chips were collected from each load and placed in drums for pulping tests at the St. Regis development laboratory in Pensacola, Fla. Total sample for pulping tests filled six 55-gal. drums.

After approximately two weeks, the pile was sampled for Forest Service moisture and specific gravity tests. The pile was sampled for Forest Service tests and for pulping tests at approximately one-month intervals for 5 months.

At each sample interval, the sloping section at the north end of the pile was removed with a payloader and about 4 ft. of the main pile was removed to expose a cross-section of the pile. After sampling, the sloping section was rebuilt and a new cross-section, previously undisturbed, was exposed for each subsequent sampling.

One-gallon samples were collected from 20 positions on the exposed cross-section, as shown in Fig. 2. These samples were used by the Forest Service for moisture and specific gravity tests, and for identification of fungi and other agencies of deterioration.

Half of each 1-gal. sample was placed immediately in a polyethylene bag, which was closed tightly with a rubber band. The bag of chips in turn was inserted into a heavy, circular ice-cream carton to facilitate safe shipment, maintenance of airtight conditions, and labeling of the samples. The other half-gallon of chips from each sample was air-dried rapidly and then handled in the same manner as the green chips. Samples arriving at the Forest Products Laboratory were placed immediately in a cold room maintained at a near-freezing temperature. Evaluation of the samples proceeded immediately after arrival in some cases, and always within a week or so after arrival. One 55-gal. drum of chips was taken from each of six positions, as shown in Fig. 2. These samples were used for pulping tests at Pensacola.

Moisture and Specific Gravity Tests at the Forest Products Laboratory

Moisture content was determined by drying the samples to constant weight in an oven at 104°C., and expressed as percentage moisture based on dry weight. These results have been recalculated to express moisture as a percentage based on wet weight, as is customary in the paper industry.

Volume determinations for calculating specific gravity were made by soaking the chips in water for about 24 hr. in the polyethylene bags in which the chips were received, transferring to a screen basket having $^1/_8$-in. openings, dunking the basket and contents in a detergent to discourage adherence of surface water, and swinging the basket at arm's length to discharge free water. The basket and chips then were suspended in a container of water counterbalanced on a scale.

Specific gravity was calculated as moisture-free weight per unit of green (soaked) volume.

Pulping Tests

Samples for pulping tests reached Pensacola by truck within three to five days. Immediately upon delivery, each drum (sampling position) was mixed thoroughly and sampled for moisture determination. Digester charges containing 3 cu. ft. of chips were weighed and placed in closed containers. These chip charges were measured by filling a 1 by 1 by 1 ft. box, compacting the chips by bouncing the box on a concrete surface (simulating compaction of chips in a rail car) and leveling the top surface. The weight per cubic foot of chips thus serves as an approximation of chip bulk density under conditions similar to those which prevail during measurement of chips received at the pulp mills.

Kraft white liquor was prepared from flake caustic and flake sodium sulfide to give 25% sulfidity. Chips were charged to the experimental digester, white liquor added to give 17% active alkali as Na_2O based on moisture-free wood. Dilution water was added to give a final active alkali concentration of 50 g.p.l. Na_2O, including the moisture in the chips. Direct steam was used to bring the cooks to 344°F. in 90 min., and the cooks were held at 344°F. for 70 min. Cooks were blown at full pressure to a cyclone separator and blow chest equipped with a drainer bottom.

The pulp was washed in the blow chest with hot water until the effluent was reasonably clear. A steam ejector below the drainer bottom was used to concentrate the pulp to about 16% consistency.

The high-density pulp was transferred to a sealed drum, sampling for consistency during the transfer. The wet pulp was weighed and total yield calculated from this weight and the consistency sample. The pulp was diluted and screened through a 0.014-in. cut flat screen, rejects were collected and weighed, and the accepted pulp rethickened for storage in sealed containers.

Screened pulps were tested by refining in a Dilts laboratory beater, which processes 10.6 lb. of pulp. A representative sample was taken at the start of the beating cycle for the 50-ml. permanganate number test (TAPPI Standard T 214 m-50). The beater roll was set at 0.012 in. for 1 hr. and lowered to 0.006 in. for the balance of the test. Samples were taken at 30-min. intervals and 97.6 g.s.m. (60 lb. (24 × 36—500)) handsheets were made on the Noble and Wood sheet machine. Five-gram Schopper-Riegler freeness tests were made on each beater sample.

Handsheets were conditioned and tested for basis weight, tear, tensile, and burst. Physical tests were expressed as "per cent," or points per pound of basis weight, and the results plotted against beating time. From the resulting plots, relative values of the physical tests were picked off and pulp quality was expressed by plotting tear versus tensile or tear versus burst.

Twelve cooks were processed for each sample period, two cooks for each position in the storage pile. Occasionally, a cook was discarded owing to operating difficulties or suspected errors which would invalidate the results. Average pulp quality for each storage period was determined by tabulating and averaging the tear versus tensile or tear versus burst data. Ninety-

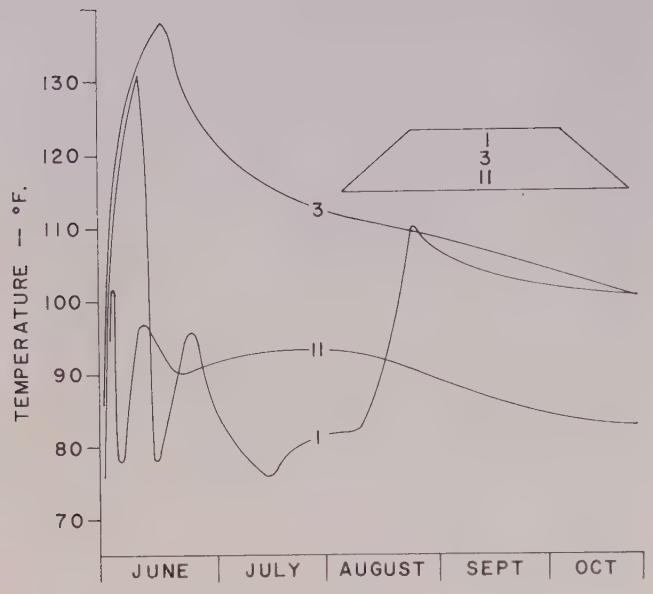

Fig. 3. Temperature variation; vertical

five per cent confidence limits were placed on these averages as a measure of the significance of apparent differences. Yields, moisture data, and wood density data were averaged and tested for statistical significance.

Causes of Deterioration in Storage

At the Forest Products Laboratory, the condition of the chip samples was appraised visually, based on experience in detecting deterioration of wood. Such inspections, supplemented by microscopical examinations and probing or breaking chips for evidences of softness, brashness, and discoloration, were used to detect the presence of mold, stain, decay, or other organisms. Standard laboratory methods of isolating and culturing fungi from wood were employed in an effort to determine the organisms causing deterioration.

RESULTS

Conditions in Pile

Temperature. Thermocouple locations 1, 2, 3, 7, 11 (Fig. 2) represent a vertical section through the center

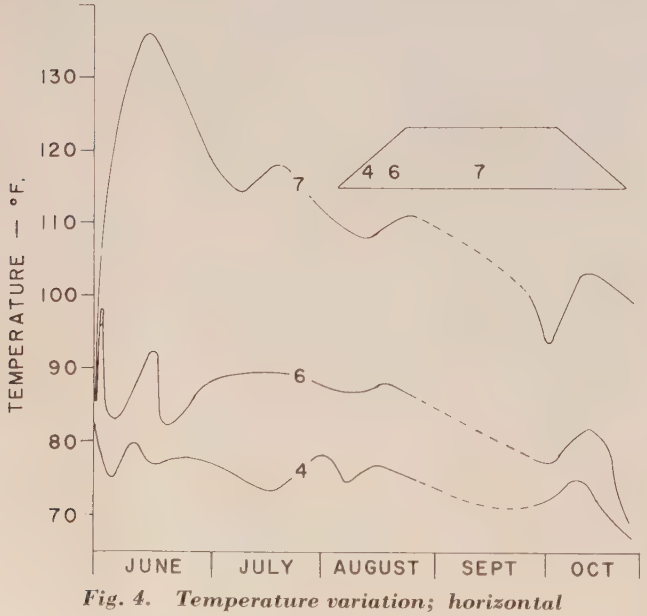

Fig. 4. Temperature variation; horizontal

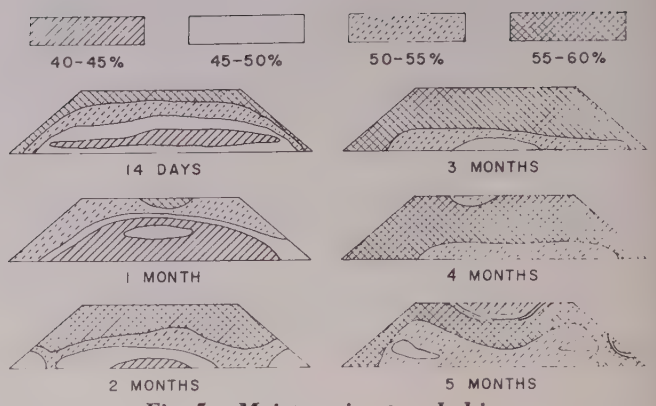

Fig. 5. Moisture in stored chips

of the pile, and locations 4 to 10 represent a horizontal section through the pile about 6 ft. from the top. In Fig. 3, the temperatures at locations 1, 3, 11 are charted as representative of the vertical section. In Fig. 4, the temperatures at locations 4, 6, 7 are charted as representative of the horizontal section.

Figure 3 shows that there was a rapid initial increase in temperature at all locations in the vertical section. At location 3, near the center of the pile, the temperature reached 138°F. in about 2 weeks, diminished sharply in the next 2 weeks to about 120°F., then diminished gradually to about 100°F. after 5 months. At location 1, near the top surface, the initial increase stopped at a lower temperature, and diminished more sharply than in the interior. After dropping back close to the initial ambient temperature, 80°F., a second increase occurred, reaching 96°F. before again diminishing to ambient temperature. In the third month, a third sharp rise in temperature occurred, reaching 110°F. and diminishing gradually through the fourth and fifth months in agreement with the interior. At location 11, near the ground level, the successive increases and decreases occurred, but lower temperatures were reached, probably owing to heat losses to the ground.

Figure 4 shows a similar pattern of successive temperature peaks for the horizontal section. The highest temperatures were reached in the center of the pile.

In general, all except the outer 18- to 24-in. shell of the pile appears to have reached high temperatures and to have stayed above ambient temperatures through five months of summer storage.

Moisture. Figure 5 shows a series of cross-sectional diagrams summarizing the moisture tests at the sampling points indicated in Fig. 2. These cross-sections show that a zone deep in the pile lost moisture soon after the pile was established. At the same time, concentric zones closer to the surface increased in moisture, suggesting that water was being driven out of the interior and condensing in the outer shell. The dry zone increased in size through the first month, concurrent with the period of highest temperature. At the end of 2 months, this trend had reversed and moisture appeared to be increasing progressively from the top down. During the third and fourth months, a fairly uniform condition was established and all zones of the pile reached moisture contents higher than the initial condition. In the fifth month, corresponding to temperature increases in some parts of the pile, several new centers of drying were observed and the pile became nonuniform in moisture content.

Table I. Loss of Wood Substance (Density) in Storage

Months in storage	Bulk density			Specific gravity			Av. cumulative loss, %	Pulpwood[a] cumulative loss, %
	lb./cu.ft.	g./cc.	Cumulative loss, %	Green sample	Air-dried sample	Av.		
0	13.7	0.219	...	0.510	0.506	0.508	...	...
1/2	...	...	...	0.505	0.508	0.506	0.5	...
1	13.5	0.216	1.5	0.498	0.506	0.502	1.1	0.4
2	13.6	0.218	0.7	0.492	0.501	0.497	2.1	1.3
3	13.2	0.211	3.6	0.484	0.493	0.488	3.8	2.7
4	13.4	0.214	2.2	0.479	0.486	0.483	4.8	4.7
5	13.4	0.214	2.2	0.467	0.476	0.472	7.0	6.6
6	...	...	...	...	...	...	...	8.4

[a] From literature reference (6).

Weather Conditions. It appears that the early changes in the pile were caused by agencies within the pile itself and were independent of surrounding conditions. The subsequent increase in moisture, to a level above the original moisture content, probably represented seepage of rainfall into the pile. Complete weather data were collected but are not considered important enough to report in detail.

Wood Density. The several test methods used in this study failed to agree, probably owing to limitations in the methods themselves. The chip bulk density test (described under Procedure) may be influenced by the fact that wet chips tend to pack closer. The test is influenced also by the technique used in packing the chips. It is a useful test which relates directly to chip pulpwood at Brunswick, Ga., started in June, is shown for comparison. The chipsappear to deteriorate at about the same rate as straw-piled pulpwood. Specific gravity loss amounted to about 7% after five months' storage. The greatest reductions occurred in the outer 3 ft. of the sloping sides of the pile.

Pulping

Yield. Table II shows the average percentage yields based on wood charged to the digester, and related cooking data. Ninety-five per cent confidence limits are shown for each average. The total yield after two months' storage was significantly lower than any previous or subsequent yield, for reasons which are not apparent. Otherwise, the total percentage volume as received, but it is the least reliable of the methods used for tracing small changes in wood density.

Forest Service specific gravity tests were made on green chips and on chips which had been air-dried after sampling. The air-drying procedure probably results in dimensional changes which are not reversed in subsequent soaking. In both cases, the procedure of soaking the chips before determining specific gravity causes some leaching of soluble material, which should not be counted as a loss of wood substance since it is measured again in the pulping yield.

Table I shows the apparent loss in wood substance by all three tests methods. The data on straw-piled yield was not influenced by five months' storage. The percentage of screen rejects was significantly lower after one-month storage, being reduced from 1.7% on the wood to 1.1% on the wood. During the remainder of the storage time, rejects appeared to increase from the very low 1.1%, but remained significantly lower than the original level. The decrease in rejects was reflected in a higher screened yield.

The pulp yields did not show any relation to moisture content of the chips, under the conditions of this study where liquor volume was adjusted to compensate for moisture changes.

Table II. Average Cooking Data
With 95% Confidence Limits On The Averages

Months in storage	Total yield, %	Rejects on wood, %	Screened yield, %	Permanganate number[a]	Chip bulk density,		Chip moisture,[b] %	Number of cooks
					lb./cu.ft.	g./cc.		
0	47.0 ± 0.6	1.7 ± 0.1	45.3 ± 0.7	22.7 ± 1.1	13.7 ± 0.2	0.219 ± 0.003	47.4	10
1	47.3 ± 0.6	1.1 ± 0.1	46.2 ± 0.5	21.9 ± 0.9	13.5 ± 0.5	0.218 ± 0.006	47.4	10
2	46.2 ± 0.4	1.3 ± 0.1	44.9 ± 0.4	22.1 ± 0.8	13.6 ± 0.2	0.218 ± 0.003	45.8	12
3	48.1 ± 0.5	1.4 ± 0.2	46.7 ± 0.5	23.1 ± 0.8	13.2 ± 0.2	0.211 ± 0.003	48.3	12
4	47.4 ± 0.6	1.4 ± 0.2	46.0 ± 0.5	24.4 ± 0.9	13 4 ± 0.1	0.214 ± 0.002	55.2	11
5	47.4 ± 0.4	1.4 ± 0.2	46.0 ± 0.4	21.4 ± 1.1	13.4 ± 0.2	0.214 ± 0.003	57.4	10

[a] TAPPI Standard T 214 m-50
[b] As received at Pensacola, Fla.

Table III. Average Physical Test Data
Tear % with 95% confidence limits

Months in storage	Tensile, %					
	20	25	30	35	40	45
0	327 ± 25.7	392 ± 30.5	448 ± 34.7	491 ± 42.0	501 ± 30.4	486 ± 24.3
1	301 ± 16.1	359 ± 20.8	406 ± 29.8	441 ± 27.4	452 ± 15.9	438 ± 12.8
2	292 ± 11.5	348 ± 14.2	385 ± 13.9	410 ± 16.6	423 ± 20.0	412 ± 22.0
3	270 ± 10.6	321 ± 25.7	357 ± 24.7	381 ± 25.7	389 ± 29.8	382 ± 30.0
4	295 ± 23.5	340 ± 24.9	358 ± 21.9	364 ± 17.5	362 ± 17.6	354 ± 18.2
5	298 ± 39.3	342 ± 38.3	365 ± 37.9	375 ± 32.7	373 ± 28.7	360 ± 28.2
	Tensile, %					
Months in storage	50	55	60	65	70	
0	453 ± 19.0	412 ± 15.6	377 ± 20.1	343 ± 23.1	309 ± 22.0	
1	417 ± 13.9	395 ± 14.7	374 ± 15.8	353 ± 15.1	326 ± 11.6	
2	386 ± 19.2	363 ± 16.0	347 ± 19.2	336 ± 43.8		
3	368 ± 26.0	353 ± 25.2	334 ± 21.2	312 ± 18.1	295 ± 16.5	
4	341 ± 18.7	326 ± 17.3	309 ± 17.2	292 ± 14.9	273 ± 10.4	
5	346 ± 23.5	332 ± 25.4	318 ± 22.9	300 ± 23.5	282 ± 29.3	

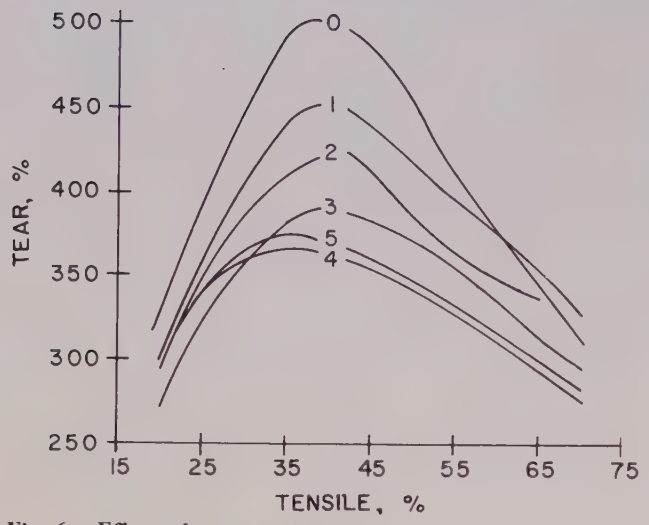

Fig. 6. Effect of storage time on tear and tensile strength

Numbers on curves indicate the storage time in months.

There were no significant differences in percentage yield among sampling positions.

Pulping Quality. Permanganate number tests are shown in Table II, with 95% confidence limits. Other than a significantly high permanganate number average for the four months' sample, storage had no effect on degree of cooking. Therefore, degree of cooking was not an important factor in the pulp strength results.

Table III shows the average pulp strength for each storage time and 95% confidence limits on these averages. As explained under Procedure, tear versus tensile was used to evaluate pulp quality. Comparable results, not shown, were obtained by using tear versus burst. Tear versus tensile averages are plotted in Fig. 6. These results show a progressive decrease in pulp strength through the fourth month of storage. There appeared to be no further loss during the fifth month (but the pulps made after five months' storage may have changed their properties owing to a delay in making the beater tests, caused by equipment failure: this delay allowed some air drying). The loss of strength was entirely a loss in tear. Maximum development of tensile was not influenced by storage, as shown by Fig. 6, nor was maximum development of burst influenced by storage, as shown in Table IV.

The pulp strength deterioration amounted to about 5% per month. Figure 7 shows the magnitude of the change more clearly; here pulp strength has been reduced to a single numerical value. To accomplish this, the product tear % and tensile % was calculated over the range of tensile development from 20 to 65% tensile. The average of these tear–tensile products is a good one-number representation of pulp strength when comparing similar pulps.

Ninety-five per cent confidence limits on the tear–tensile products are included in Fig. 7. Inspection of these confidence limits shows that the change in pulp strength was not statistically significant from one month to the next, but was significant over any two-month interval. Since the change was progressive and very consistent over 4 successive months, it is highly probable that the observed changes were real and not experimental. The apparent slight increase in strength between the fourth and fifth months was not significant.

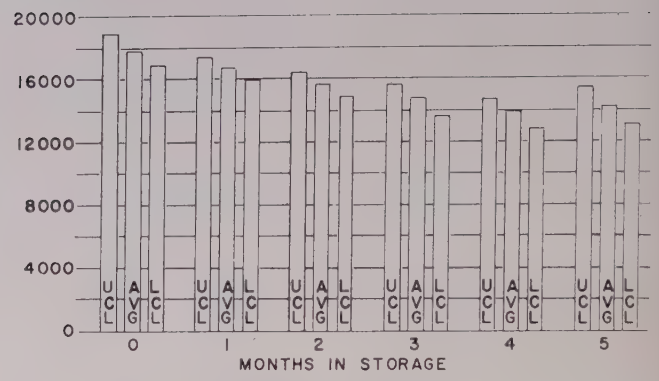

Fig. 7. Pulp strength factor vs. storage time with 95% confidence limits

In assessing the amount of strength loss caused by storage, it must be remembered that the base-line data for this study were obtained from cooks made very quickly after the trees were cut. Wood never reaches a mill digester so quickly and commercial pulps never have strengths as high as the control pulps for this experiment. Factors other than wood also contribute to this difference.

Table V compares the pulp strengths from the upper and lower portions of the storage pile. During the first month, there was no difference between the upper and lower portions. During the balance of the test, the lower portion deteriorated more rapidly than the upper portion.

A brief pulping test reported by J. S. Martin at the Forest Products Laboratory may explain the difference between upper and lower portions of the pile. Two cooks were made from bright chips and two cooks from darkened chips taken from the Fargo test pile

Table IV. Maximum Mullen Burst Development

Months in storage	*Av. maximum Mullen burst, %*	*Number of cooks in av.*
0	122	10
1	123	10
2	106	12
3	125	12
4	125	11
5	123	10

after five months' storage. In this experiment it was observed that the darkened chips gave about 2% lower total yield and 18 to 20% lower tearing strength. On the basis of only two cooks in each category, the results will not stand statistical scrutiny and 2% difference in yield is not significant. The difference in tear could be a real difference. The greatest areas of darkened chips were in the sloping sides of the pile and the discoloration penetrated close to the "bottom left" and "bottom right" sampling positions used for our pulping tests.

Table VI shows the initial (unbeaten) pulp freeness averages for each period. Chip storage caused a progressive reduction in initial freeness. The most obvious explanation for this effect is that the fiber was weakened and more easily broken during the digester blow, washing, screening, etc. The same action could account for the fact that the loss of strength was entirely a loss of tear.

The observed loss of pulp strength amounting to about 5% per month and the observation that this loss shows up in tearing strength agrees quite closely with

reported results of the effects of storage of pulpwood (see Literature Survey).

Causes of Deterioration in Storage

The first change in appearance of the chips was an orange stain which was evident throughout the storage period. The extent of this orange stain bore no relation to time nor to location in the pile. It apparently was not of fungus origin and seemed to have little effect on the wood. Heat and moisture were suspected as contributing factors in producing the orange stain. The orange color seemed to be prevalent in heartwood chips and on microscopical sections the color appeared around the walls of resin ducts, suggesting that the color was caused by modification of resins.

Heavy fungus infection was associated with the largest reductions in specific gravity of the chips. Significant infections first appeared in the samples from the outer 1 to 2 ft. of the sloping sides of the pile. After five months' storage, this zone of heavy infection had extended inwardly several feet, but the center of the pile still showed little infection.

Table VII shows the occurrence of molds, stains, and decay at the various sampling locations. Fungus infection first appeared as a greenish mold or light stain after a one-month storage. This type of infection, apparently caused by a *Gliocladium species*, produced only surface discolorations and shallow penetrations of the chips. Molds of this type are not known to attack the cell walls in the wood, apparently living on material leached out of the wood. In fact, it has been observed that surface molds inhibit the establishment of rot-producing fungi.

A dark staining of the chips first appeared after 2 months, and affected half of the chips after 4 months. Dark stained wood showed soft-rot attack, apparently caused by an *Alternaria*-like fungus. Softening and brashness of dark stained wood were evident in a few samples after three months and increased with longer storage. Soft-rot fungi of this type tend to penetrate and form large cavities within the highly cellulosic secondary walls of fibers or tracheids; in contrast, typical wood-decaying fungi form bore holes by penetrating directly through the walls or cause a general thinning of the fiber structure.

Typical decay caused by *Basidiomycetes* was suspected to have caused important deterioration of the chips, but efforts to prove the presence of these fungi were unsuccessful owing to the interference of the dark stain. Toward the end of the storage period an increasing proportion of chips showed an abnormal brown color that was associated with a hyaline fungus of unknown significance and detected only by microscopical examination.

Table V. Comparison of Pulp Strength—% Tear vs. % Tensile Upper Portion of Pile vs. lower Portion

Months in storage		*Tensile, %*										
		20	*25*	*30*	*35*	*40*	*45*	*50*	*55*	*60*	*65*	*70*
		Tear, %										
1	Upper Portion	308	359	395	424	444	433	412	392	372	352	332
	Lower Portion	294	358	416	457	459	443	421	397	376	353	323
	Difference	−14	−1	+21	+33	+15	+10	+9	+5	+4	+1	−9
2	Upper Portion	295	348	381	408	436	434	408	381	359	360	
	Lower Portion	290	347	388	413	411	390	364	344	327	312	
	Difference	−5	−1	+7	+5	−25	−44	−44	−37	−32	−48	
3	Upper Portion	267	312	352	387	413	413	398	384	361	335	310
	Lower Portion	272	330	362	374	364	350	337	322	306	289	272
	Difference	+5	+18	+10	−13	−49	−63	−61	−62	−55	−46	−38
4	Upper Portion	306	354	370	378	381	373	360	344	326	306	287
	Lower Portion	283	327	346	349	344	334	322	308	293	278	264
	Difference	−23	−27	−24	−29	−37	−39	−38	−36	−33	−28	−23
5	Upper Portion	345	396	418	413	396	380	364	349	336	321	
	Lower Portion	275	315	338	356	361	351	337	324	308	289	
	Difference	−70	−81	−80	−57	−35	−29	−27	−25	−28	−32	

Table VI. Initial (Unbeaten) Freeness

Months in storage	*Av. freeness, 5 g. °S.R.*	*Number of cooks*
0	810	10
1	781	10
2	783	12
3	743	12
4	723	11
5	708	10

CONCLUSIONS

Outside Storage in the South

1. Outside summer storage of pine wood chips in the south is feasible. Losses in yield and pulp quality are no greater than those observed in roundwood storage under similar conditions:

Table VII. Type, Location, and Degree of Fungus Infection

Months in storage	*Type of infection*	*Sides of pile near surface*[a]	*Interior sides of pile*[b]	*Center*[c]
		Average percentage of chips infected		
1	Mold or light stain	1	8	None
	Dark stain	None	None	None
	Decay	None	None	None
2	Mold or light stain	42	None	None
	Dark stain	11	None	None
	Decay	None	None	None
3	Mold or light stain	35	1	3
	Dark stain	22	None	None
	Decay	None	None	None
4	Mold or light stain	14	14	4
	Dark stain	67	1	1
	Decay	13	None	None
5	Mold or light stain	21	20	3
	Dark stain	42	5	None
	Decay	40	8	None

[a] Sampling locations 1*A*, 1*B*, 2*A*, 2*B*, 1*E*, 1*F*, 2*E*, 2*F*.
[b] Sampling locations 3*A*, 3*B*, 3*E*, 3*F*.
[c] Sampling locations 1*C*, 1*D*, 2*C*, 2*D*, 3*C*, 3*D*, 4*A*, 4*B*.

(a) Loss of wood substance amounts from 1 to 1.5% per month.
(b) There is no loss in percentage yield based on wood charged to the digester.
(c) Loss of pulp strength amounts to about 5% per month. This loss is a loss of tearing strength.

2. Temperature inside a chip storage pile increases as much as 60°F. in the first few weeks. Elevated temperature persists through five months' storage, except in the outer shell. Successive waves of increasing temperature are characteristic and the temperature in the pile bears no relation to surrounding ambient temperature, indicating that the heat is generated within the pile.

3. Moisture is driven out of the high temperature zone in the center of the pile in the first weeks and appears to condense in the cooler outer zones. When the initial high temperature subsides, rainfall seeps into the pile from the top and the entire pile reaches a uniform moisture level higher than the original condition.

4. Permanganate number of pulps produced with constant conditions is not influenced by the action in the storage pile. The proportion of screen rejects is reduced significantly.

5. Fungus infection first appears after 1 month as a greenish mold or light stain, mostly on the surface of the wood. A dark stain, associated with soft-rot attack, appears after 2 months and increases thereafter. The dark stain obscures the observation of typical wood decay. Fungus activity leading to deterioration is most prevalent in in the sloping sides of the pile.

Outside Storage on West Coast

Observations and information obtained from west coast mills indicate that the attack on the wood is influenced by the way in which the storage pile is built. Larger piles have less exposed surface, and can be compacted to a greater degree and, therefore, are less subject to deterioration. The Forest Service study associated with this project indicated that fungi are in fact suppressed in the interior of the pile.

Air-borne contamination with fly-ash and other foreign material is a problem which was not included in this study. The worst problem on the west coast is carbon from bark and refuse burners, aggravated by the use of hogged fuel for home heating.

Plant discharges can be controlled by installation of centrifugal multiclone cleaners or other equipment. Foreign material in the chips going to the digester can be minimized by careful location of the storage piles and by screening the chips after recovery from storage.

Nonuniformity of chip moisture content can create a major operating problem through loss of control over dilution and liquor concentration. In this study, where moisture content was known and adjustments made in liquor dilution, the variation in chip moisture did not influence pulp yield and quality. A condition was reached after several months where the moisture content was uniform but it is questionable whether the optimum storage period is long enough to reach this condition. Also, the moisture at this point is uniformly high, which may be undesirable owing to the additional load on evaporators.

One solution to the problem of nonuniform chip moisture is to recover chips from storage in a way which blends the chips to give uniform *average* moisture from digester to digester.

All comparisons between the effects of chip storage and roundwood storage in this study have been based on information extracted from the literature. Since completion of this work another test pile was constructed during the winter months and at the same time a roundwood pile was constructed.

Sample intervals were to be at 3 and 6 months. At this time the 3 months' samples have been tested but the data for the six-month samples are not available.

These data tend to verify the work in this report and the results in brief, are as follows:

1. Strength loss (tear) again appears to be about 5% per month for both roundwood- and chip storage.

2. Pulp viscosities are the same for both roundwood- and chip storage.

3. Total yields and permanganate numbers are the same for both roundwood- and chip storage but the percentage of rejects is slightly lower in pulp from chip storage.

4. Specific gravity loss appears to be greater in chip storage but only a few tests were run on the roundwood and the wide range of values does not make the difference significant. More complete tests will be run on the six months' samples.

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APPENDIX

NOTES ON TEST PROCEDURES

Noble and Wood Sheet Making Procedures

Sixty-pound (24 × 36—500) handsheets are made for test purposes. Wet press roll pressure is set to bring the sheet moisture to 65%. The temperature in the drum drier is set at 240°F. and the speed adjusted to lower the sheet moisture to 3%. The sheets are peeled from the wires and allowed to condition at 73°F. and 50% R.H. for 24 hr.

Physical Test Procedures

Basis Weight. Determined by weighing four 7 by 7-in. sheets at one time on a precision balance. The weight, in grams, is converted to pounds per ream.

Tensile. Eight tensile strips, 7 by 1 in., are cut from four sheets. These are pulled on a Schopper, pendulum

type tensile tester using 1-in. jaws with a 4-in. span. The eight tensile values are averaged. The tensile value in pounds × 100 is divided by the basis weight and the result expressed as per cent tensile.

Tear. Four strips, 63 mm. by 7 in., are cut from four sheets. Four tears are made (four sheets together) with the Elmendorf tearing tester. The total of the four tear values in grams × 100 is divided by the basis weight and expressed as per cent tear.

Mullen. Four strips, 64 mm. by 7 in., are cut from four sheets. Three bursts are made on each strip wire and felt sides down alternately. The average Mullen value in pounds × 100 is divided by the basis weight and the result expressed as per cent Mullen.

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An Analysis of Air-Impingement Drying

R. A. DAANE and S. T. HAN

The use of high-velocity air jets impinging on the surface of paper to increase drying is an important technological advance in the paper industry. This paper aims at providing an engineering basis for the evaluation of the impingement method of drying. Although evaporative drying of paper is a fairly complicated process, involving several mechanisms of heat and mass transfer, particularly when the paper approaches final dryness, it is clear that moisture removal requires equivalent heat transfer to the sheet. Based on the boundary-layer concept and dimensional considerations, heat transfer from a solid surface under air impingement is considered. Under practical operating conditions, both jet and boundary layer are turbulent. Using a dimensionless form consistent with that assumption, a general correlation of available heat transfer data for the case of a single two-dimensional jet and for the case of multiple round jets is attempted. The important parameters are Nusselt number, Reynolds number, Prandtl number, and a geometrical factor. An index of performance, a number indicative of heat transfer rate under conditions of constant expenditure of power required to force air through the system, is defined and evaluated for various systems. The application of air impingement to paper drying is discussed.

It is well known that heat transfer by forced convection of a fluid near a solid surface is governed largely by the dynamics of fluid flow. An analysis of air-impingement drying, therefore, begins with a study of the behavior of a jet and its impingement on a solid surface.

NOMENCLATURE

A_f = ratio of total orifice cross-sectional area to heat transfer area
b = diameter of a round orifice or width of a slot
c = specific heat of air
C_1 = an experimentally determined constant indicative heat transfer coefficient under conditions of fixed rate of flow
C_2 = index of performance, a number indicative of heat transfer rate under conditions of constant air-pumping power expenditure
C_d = orifice flow contraction coefficient
$h, \bar{h}$ = local heat transfer coefficient and average heat transfer coefficient, respectively
k = thermal conductivity of air
K = a conversion factor
L = the maximum distance along the heat transfer surface between a point of impingement and the spent air-removal edge of the impingement system
m, n = experimentally determined exponents
P = air-pumping power per unit area of heat transfer surface
q = heat flux
r = radial distance along the heat transfer surface from the center line of a round jet
R = the radius of a circle described on the heat transfer surface over which the heat transfer coefficient is averaged
T = temperature at point indicated by subscripts defined where used
U = air velocity
x = distance along the heat transfer surface from the center line of a two-dimensional jet
X = the distance from a two-dimensional jet center line over which the heat transfer coefficient is averaged
y = axial distance from the jet origin to the heat transfer surface
α = an experimentally determined constant
δ = air boundary layer thickness
μ = kinematic viscosity of air
ρ = density of air
$\phi(y/b, x/b)$ = an experimentally determined function expressing the dependence of local heat transfer coefficient on the axial ratio, y/b, and on the distance ratio along the heat transfer surface, x/b
$_0$ = subscript, used to indicate that a quantity is evaluated at the point, $x = y = 0$

DYNAMICS OF AIR-IMPINGEMENT

A free jet occurs when a fluid is discharged from a boundary opening into a large space. If the fluid were inviscid, the jet would retain its shape and velocity indefinitely in the absence of external forces. A jet of real fluid, however, entrains the surrounding fluid as a result of the viscous or turbulent action. Consequently, its mass flow increases, its boundary spreads, and its velocity decreases in the downstream direction. It is generally accepted that the total momentum in a jet remains constant.

At very low discharge velocities, the jet is laminar. As the velocity increases, the jet becomes turbulent. The transition from laminar to turbulent flow depends upon not only the velocity but also fluid properties and flow geometry, and is characterized by the Reynolds number representing the ratio of inertial to viscous forces.

For a free jet, the Reynolds number may be defined as

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$$Re_0 = \frac{\rho_0 U_0 b}{\mu_0} \quad (1)$$

where b is the diameter of a round opening or the width of a slot. The critical Reynolds number at which a round jet becomes turbulent has been recently estimated by Vickers (*1*) to be in the range of 1000 to 2000. Since the discharge velocity of air jets concerned here generally is between 100 and 500 f.p.s., Re_0 is at least 2×10^4 for a $^3/_8$-in. jet at room temperature and atmospheric pressure. The jets in practical use are, therefore, highly turbulent.

As a turbulent jet emerges from the opening, the velocity is nearly uniform at U_0. Immediately, it reacts with the surrounding fluid and its boundary expands. The inner part of the discharged fluid which has not yet become part of the ever-growing zone of diffusion is called the potential or irrotational core, its velocity remaining at U_0. The core ends where the zone of diffusion reaches the center line of the jet. Downstream from this section, the center line or maximum velocity of the jet must decrease as the diffusion zone further expands. Thus, the velocity profile in a jet is a complex function of the distance from the opening.

The length of the potential core is indicated to be about 3 to 5 diameters (*2*). Beyond the core, the center line velocity, $U_{max.}$, has been theoretically deduced (*3*) and experimentally verified (*2*) to be proportional to the axial ratio, b/y, for a round jet and to $(b/y)^{1/2}$ for a two-dimensional jet such as one issuing from a long, narrow slot. The center line velocity of a two-dimensional jet may decrease to one-third of its discharge velocity, U_0, at an axial distance $y/b = 60$.

Under the assumption that the velocity profiles beyond the potential core are nearly similar, it follows that the average velocity of the jet follows the same relationship as $U_{max.}$, i.e., for a round jet:

$$\frac{\bar{U}}{U_0} \sim \frac{b}{y} \quad (2)$$

and for a two-dimensional jet:

$$\frac{\bar{U}}{U_0} \sim \left(\frac{b}{y}\right)^{1/2}. \quad (3)$$

For application to air-impingement drying, we are interested in jets having smaller values of y/b than that at which the potential core ends, as will be discussed later. With very small values of y/b, the velocity distribution approaches that of the uniform jet emerging from the orifice. Therefore, for cases of interest, it is probably correct to consider the velocity distribution as being characterized by a complicated but small deviation from the uniform discharge velocity.

When a stream of fluid impinges on a rigid, nonporous, smooth, and flat plate, the flow diverges symmetrically along the plate from the center of impingement to be designated as a point of stagnation. If the fluid were inviscid, the flow after impingement would be parallel to the plate with the same velocity as U_0 except for that in a region within a small horizontal distance from the stagnation point. According to the theory of potential flow (*4*), the region of the velocity directional change is confined within a distance along the plate surface equal to b. In the case of a turbulent jet and a real fluid, the velocity profile approaching the plate is symmetrical but nonuniform. While the pattern of flow along the plate in the space of impingement must be traceable to that of the approaching jet, no analysis has yet been suggested.

If a flat plate is immersed in a uniform stream of velocity U parallel to the plate, the flow parallel to the plate retains almost the same velocity U at any point remote from the plate surface. The velocity gradient is confined within a thin layer of fluid flowing along the plate. At the surface of the plate, the velocity is zero, but the gradient is finite. This layer within which the velocity gradient is confined is called the boundary layer in the modern concept of fluid mechanics. The thickness of the boundary layer δ is defined as the distance from the plate to the edge of the boundary layer at which the velocity may be arbitrarily set to be 0.99 of U. The thickness increases with the distance from the leading edge of the plate. It has been established that the thickness of the boundary layer is a power function of the Reynolds number defined as $\rho Ux/\mu$.

For laminar flow:

$$\frac{\delta}{x} \sim \left(\frac{\rho Ux}{\mu}\right)^{-1/2} \quad (4)$$

and for turbulent flow:

$$\frac{\delta}{x} \sim \left(\frac{\rho Ux}{\mu}\right)^{-1/5}. \quad (5)$$

The friction coefficient varies with the Reynolds number in a similar manner.

For a flat plate immersed in a uniform stream parallel to the direction of flow, δ/x is 0.013 at the Reynolds number of 10^5 if the boundary layer is laminar and 0.028 at the same Reynolds number if the boundary layer is turbulent.

The critical Reynolds number is usually recognized to be about 5×10^5. However, if the approaching stream is highly turbulent and factors causing flow disturbances exist at the plate, it can be as low as 10^4. For air-impingement drying under practical operating conditions, because of the high turbulence in the jet and the rough surface of the paper, the flow after impingement is more likely to be turbulent than laminar. This point of view is directly opposed to that of Gardner (*5*). In his treatment of high velocity air drying, he considered the boundary layer to be laminar.

In the laminar boundary layer, momentum transfer is accomplished by molecular motion or viscous action. The transmission of shear and the dissipation of energy in the turbulent boundary layer are much more complex. Very close to the plate there is an extremely thin sublayer which is laminar by all indications. Above this laminar sublayer a buffer or transition zone exists in which both viscous and inertial actions are important. Farther away from the plate, turbulence prevails. Both laminar sublayer and buffer layer are subject to oscillations. As a whole the transfer of momentum is much more effective in a turbulent than a laminar boundary layer.

HEAT TRANSFER UNDER A SINGLE JET

The transfer of heat between a solid surface and a fluid in forced convection is analogous to the transfer of momentum. Using this analogy, it can be shown

that the Nusselt number representing the ratio of heat transfer by convection to conduction should be a function of the Reynolds number and Prandtl number, which is simply the ratio of kinematic viscosity to thermal diffusivity of the fluid. Experimental heat transfer data are, therefore, correlated by these dimensionless groups, most frequently as a power function:

$$Nu = \alpha(Re)^m(Pr)^n \tag{6}$$

where n is usually equal to $^1/_3$.

The case of heat transfer from a flat plate immersed in a parallel stream of velocity U has been analyzed according to the boundary layer theory for both laminar and turbulent flow. The local heat transfer coefficient, h, at a distance, x, from the leading edge of the plate at a uniform temperature, T_s, immersed in and parallel to a uniform fluid stream of velocity, U, and temperature, T_0, is defined by:

$$h = \frac{q}{T_s - T_o} \tag{7}$$

where q is the local heat flux and $T_s - T_0$ is the heat transfer driving force. A theoretical analysis by Pohlhausen (*6*) of the laminar boundary layer gives the solution:

$$\frac{hx}{k} = 0.324 \left(\frac{\rho U x}{\mu}\right)^{1/2} \left(\frac{c\mu}{k}\right)^{1/3}. \tag{8}$$

It is noted that in this analysis the thermal boundary layer is close to but not identical with the hydrodynamic boundary layer previously discussed. In the case of air for which the Prandtl number is roughly unity, the two boundary layers may be considered to have the same thickness and the momentum and heat transfer to have the same pattern.

The analysis of the turbulent boundary layer is based on the similarity of momentum and heat transfer. According to the concept of similarity, the heat transfer coefficient can be related to the friction coefficient in a simple manner. The Colburn analogy (*7*) which is empirical by nature but useful in application yields:

$$\frac{hx}{k} = 0.0292 \left(\frac{\rho U x}{\mu}\right)^{4/5} \left(\frac{c\mu}{k}\right)^{1/3}. \tag{9}$$

By comparing equations (8) and (9), it is seen that the turbulent heat transfer coefficient is three times larger than the laminar one at the Reynolds number of 10^5. This is the reason for using high-velocity flow, so far as heat transfer is concerned.

Heat transfer by convection from a round jet of hot air impinging on a plain surface has been investigated by Perry (*8*). He found that for axial ratios $y/b > 11$ the heat transfer coefficient was proportional to the jet discharge velocity to the power of 0.7 to 0.8. Since the value of Reynolds number in his work was as low as 7000, we can safely conclude that under practical operating conditions of drying, for which Reynolds number exceeds 10^4, the flow is turbulent, not laminar. Perry's results indicated that there was about a two-fold increase in heat transfer from parallel flow to vertical impingement at the same velocity. His results also showed that a single curve of $h(r)/h$ (center) vs. r/y prevailed for all cases studied, regardless of nozzle size, velocity, or distance from the surface. This is equivalent to saying that $h(r)/h$ (center) is a function only of r divided by the effective radius which a free jet would have at the axial distance y from the orifice, in view of the observation (*2*) that for large axial ratios, y/b, the effective size of a free round jet is directly proportional to the distance y.

As will be apparent from the results to be presented, larger values of average heat transfer coefficient for a given amount of power expenditure per square foot of heat transfer surface are obtainable with values of y/b which are smaller than those at which the potential core ends. For these moderate values of y/b, neither the center line velocity of the jet, nor its average velocity, nor its size vary as a simple function of y/b, and equations (2) and (3) are not applicable. In fact, the center line velocity is almost the same at the point of impingement as the discharge velocity of the jet. Therefore, it is more appropriate to use this discharge velocity, rather than some velocity which is a function of y/b, in the definition of Reynolds number. Furthermore, the characteristic size of the system, as used in Reynolds number, and in the Nusselt number, is more appropriately represented by the orifice size b rather than the distance y. For the small ratios y/b of interest, the jet does not expand in size appreciably, but rather the size of the flow stream, both before and after impingement, is almost entirely governed by the size of the orifice, b. Nor do we have, in our problem, a free stream at large distances above the plate surface, as in the case of a flat plate immersed in a parallel stream of uniform flow. Furthermore, the turbulence in the impingement stream is generated in its emergence from the orifice and within the region of impingement to a greater extent than during its flow parallel to the plate surface. This is indicated by the fact that heat transfer coefficients with air impingement are much larger than would occur if air at the same velocity were traveling continuously parallel to the plate surface. Therefore, the significant size of the system is not directly related to distance x or distance r from the impingement center line, but, instead, it may be expected that the appropriate definition of Reynolds number is:

$$\left(\frac{\rho U_0 b}{\mu}\right)$$

and of the Nusselt number is hb/k. Then we express the dependence of heat transfer coefficient on y/b and on x/b as a function, $\phi(y/b, x/b)$, to be determined experimentally. This leads to the proposed correlation form for two-dimensional jets:

$$\frac{hb}{k} = \left(\frac{\rho U_0 b}{\mu}\right)^m \left(\frac{c\mu}{k}\right)^{1/3} \phi_2 \left(\frac{y}{b}, \frac{x}{b}\right) \tag{10}$$

and for round jets:

$$\frac{hb}{k} = \left(\frac{\rho U_0 b}{\mu}\right)^m \left(\frac{c\mu}{k}\right)^{1/3} \phi_3 \left(\frac{y}{b}, \frac{r}{b}\right) \tag{11}$$

Experiments were performed at Beloit Iron Works by Daane and Pantaleo (*9*) in which local heat transfer coefficients under a two-dimensional jet were obtained. These experiments consisted of mounting a movable 4-in. long slot of adjustable width over a fixed plate of Micarta, in which a narrow strip of graphite was embedded flush with the plate surface and parallel to the long axis of the slot. The graphite strip was electrically heated, and the heat so generated was removed by air from the slot directed normal to the

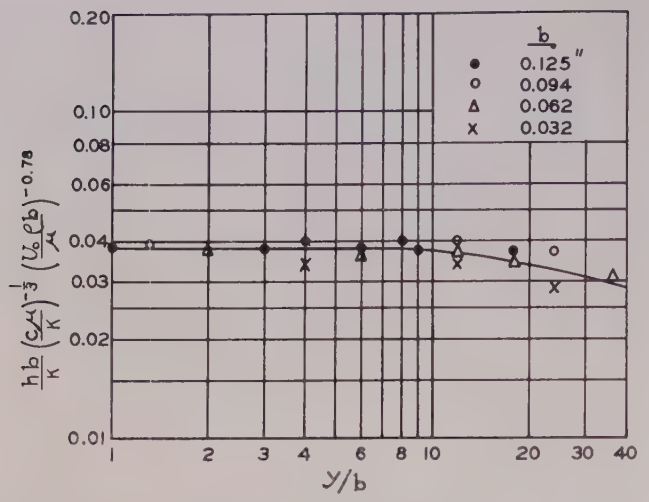

Fig. 1. The variation of local heat transfer coefficient under the center line of a two-dimensional jet with axial distance ratio y/b

plate surface. They evaluated heat transfer at the graphite strip in various geometrical arrangements in relation to the slot.

The local heat transfer coefficient was defined and calculated as:

$$h = \frac{q}{T_s - T_0} = \frac{JEI}{wZ(T_s - T_0)} \qquad (12)$$

where

T_s = temperature of the graphite strip.
T_0 = temperature of the supply air.
E = voltage.
I = current.
J = thermal equivalent of electrical power.
w = width of the graphite strip.
Z = length of the graphite strip.

By measuring the plate temperature at a series of points along x on one side of the strip, an attempt was made to correct the measured value of h for the heat loss through the Micarta. Their experiments with a single slot covered the following range of conditions:

Discharge velocity of the jet, U ..... 88–260 f.p.s.
Temperature of the supply air, T_0 ..... 75°F.
Temperature of the graphite strip, T_s ..... 100–150°F.
Width of the slot, b ..... 0.0026–0.0078 ft.
Horizontal distance of the graphite strip from the slot, x ..... 0–0.21 ft.

The range of h obtained under these conditions was from 36 to 72 B.t.u. per(hr.)(sq. ft.)(°F.)

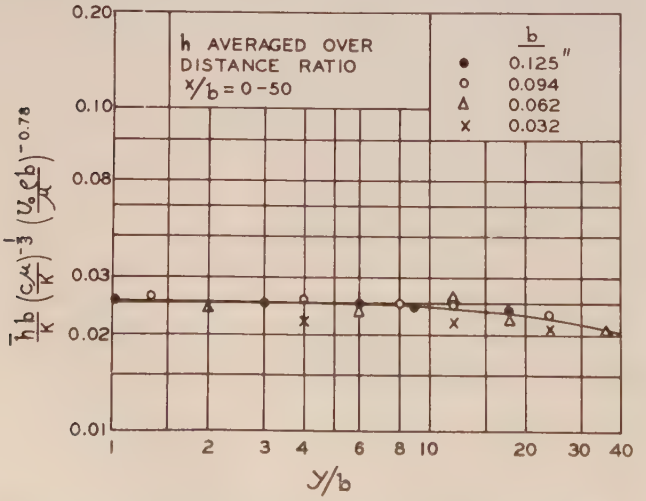

Fig. 2. The variation of average heat transfer coefficient under a two-dimensional jet with axial distance ratio y/b

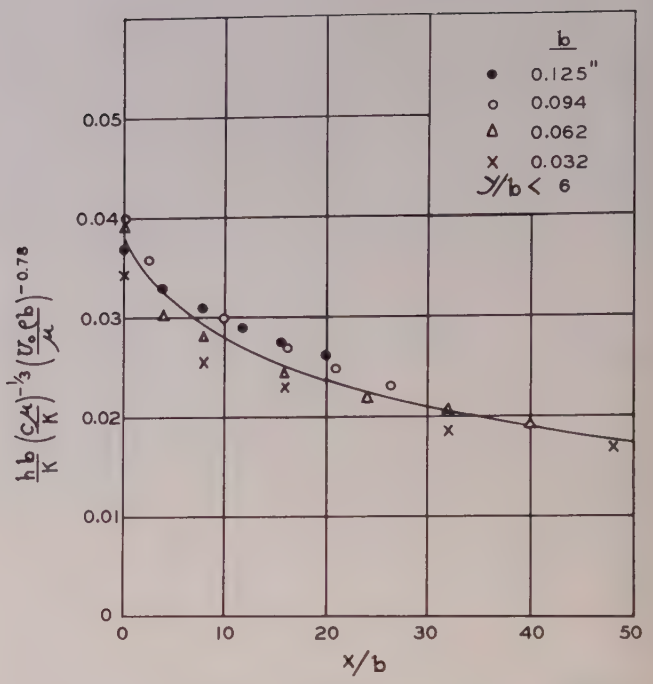

Fig. 3. The variation of local heat transfer coefficient under a two-dimensional jet with distance along the surface from the jet center line

The data obtained in these experiments are shown in Figs. 1–4, using the correlation form given by equation (10), with $m = 0.78$ and $n = 1/3$. In these experiments, the variation of Reynolds number was not systematic enough to lead to a determination of m. This exponent was set equal to 0.78 to agree with the results of Freidman and Mueller (*10*). Figure 1 shows the variation with y/b of the local heat transfer coefficient right under the jet center line. Figure 2 shows the variation with y/b of the average heat transfer coefficient, $\bar{h}$, averaged over a distance ratio $x/b = 50$. These figures show that the heat transfer coefficient does not depend significantly on y/b when that ratio is less than about 6, which covers the range of interest for air-impingement drying.

It may also be noted, referring to equation (9), that the average value of heat transfer coefficient, averaged over a surface area which is considerably larger than the cross-sectional area of the slot, is greater than that which would exist if air were flowing with the same velocity parallel to the heat transfer surface. This is again consistent with the contention that the heat transfer is governed more by the turbulence

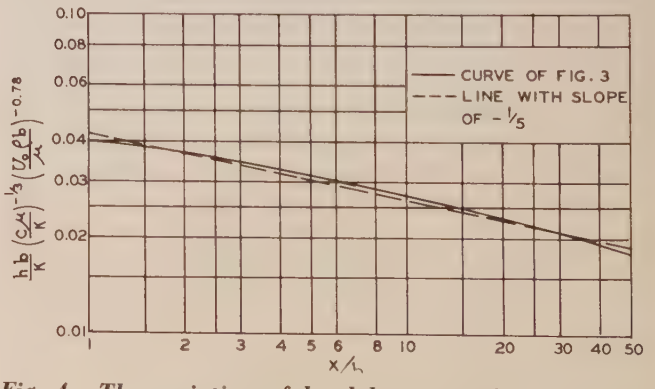

Fig. 4. The variation of local heat transfer coefficient under a two-dimensional jet with distance along the surface from the jet center line

generated in the emergence of the jet from the orifice and during impingement, than by a flow pattern established exclusively by the flow of a deep stream over the heat transfer surface.

Figure 3 shows the variation of local heat transfer coefficient with x/b for values of y/b less than 6. Figure 4 shows that, except very near the jet centerline, the local heat transfer coefficient varies approximately as

$$(x/b)^{-1/5}.$$

It is interesting to note that this variation of h with x/b, considered in conjunction with our correlation form, equation (10), leads to the same variation of h with distance, x, as that given by equation (9) for the heat transfer from a flat plate immersed in a parallel stream of uniform velocity.

Aside from the experimental scatter exhibited by the data shown in these four figures, it is apparent that there is a trend of increasing values of

$$\frac{hb}{k}\left(\frac{c\mu}{k}\right)^{-1/3}\left(\frac{U_0 b}{\mu}\right)^{-0.78}$$

with increasing values of slot size, b. This would indicate that the form of the correlation is not completely correct, since dimensional requirements preclude any such direct dependence of the quantity plotted on slot size, b. However, it is felt that this trend appears as a result of two experimental errors. The slots were not perfectly uniform in width, and very likely the actual effective sizes of the slots were larger than the nominal sizes, leading to an overestimate of velocity, U_0, which was calculated as measured flow rate divided by slot area. This deviation is probably greater with the smaller width slots. Secondly, the measured values of h are not truly local values, but are average values over some finite distance because the heat loss by conduction through the Micarta was not taken into account with sufficient accuracy. This unaccounted heat loss reduces the measured values of h to a greater extent with the smaller slot sizes.

No data appear to be available, for small values of y/b, for the variation of local heat transfer coefficient with distance from jet center line for round jets. In the case of round jets, the surface area covered by the impingement flow varies as the square of r, while with two-dimensional jets, the surface area covered varies as the first power of x. Because of this we may expect that the dissipation of turbulence, and consequently the decrease of local heat transfer coefficient, will be faster with distance from the jet center line with round jets than with two-dimensional jets. However, the dissipation of turbulence is probably a function, not only of surface area traversed by the stream, but also to some extent of the distance of travel. Therefore, it may be expected that local heat transfer coefficient will decrease less fast with surface area traversed in the case of round jets, and that the average values of heat transfer coefficient will be greater for a given ratio of orifice area to surface area over which the average is taken, in the case of round jets as compared with two-dimensional jets, for the same jet velocity.

HEAT TRANSFER UNDER MULTIPLE JETS

Air-impingement driers are usually operated with multiple jets over a rotating cylinder. The jets discharge either from rectangular slots or round orifices. For practical purposes we are interested in the average heat transfer coefficient over the surface covered by the impingement system. If, in a multiple-jet system, with the jets uniformly spaced over the total heat transfer surface, the exhaust flow of the spent impingement air did not interfere with the impingement flow, then the heat transfer pattern under all jets would be the same. In that case, the average heat transfer coefficient for the system would be, for two dimensional jets:

$$\bar{h} = \frac{1}{X}\int_0^X h\,dx \qquad (13)$$

where $X = b/2A_f$, and where A_f is the ratio of total orifice area to total heat transfer surface area. For round jets, we would have

$$\bar{h} = \frac{2}{R^2}\int_0^R hr\,dr \qquad (14)$$

where $R = b/(2\sqrt{A_f})$. The amount of interference with the impingement flow due to the spent air exhaust flow will depend on the system design. For the simple design in which the impingement system consists of a perforated plate placed a distance y above the heat transfer surface, and where the exhaust air must travel toward one edge of the perforated plate to be removed, the amount of this interference will be a function of $A_f L/Y$, where L is the maximum distance of travel of spent air between the point of its impingement and the edge of the perforated plate. In practice, it is not feasible to make the value of $A_f L/Y$ small enough so that there will be absolutely no interference. However, if this value is less than about 0.2, we may expect that the interference will be small. The jets themselves and the important part of the flow immediately after impingement occupy only a small part of the volume under a typical impingement system, leaving a large amount of space for the flow of spent air toward the exhaust edge of the system. Then if the velocity of this exhaust flow is a small fraction of the jet velocity, the interference will not be large.

Freidman and Mueller (*10*) presented the results of several experiments for average heat transfer under multiple jets. Their apparatus consisted of a hot plate, 1 ft. wide by 2 ft. long in effective dimensions, and a perforated plate placed directly above the heat transfer surface. Three sides of the apparatus were enclosed so that air flowed in the direction of the plate only. In all experiments, the basic geometry was given, except for the orifice pattern. Condensing steam was used to supply heat under the bottom plate. The supply air temperature was 86°F., but the surface temperature of the plate was not specified. They measured the average heat transfer coefficients for the whole plate under various combinations of orifice size, plate spacing, ratio of orifice to plate area, and mass velocity (mass flow rate per unit heat transfer area). They concluded that the average heat transfer coefficients are proportional to the mass velocity to the power of 0.78, and showed graphically the effects of other important variables.

A summary of Freidman and Mueller's results, for the cases where the orifice geometry was known not to be complicated by vanes or nozzles, is given in Table I. The data shown in this table, with some modi-

fications, are plotted in Fig. 5, using the correlation form given by equation (11). The values of b and of A_f given in the table were corrected to account for the contraction of the jet at the orifice, using the relationships:

$$A_f \text{ (effective)} = A_f \text{ (given)} \cdot C_d$$

and

$$b \text{ (effective)} = b \text{ (given)} \cdot \sqrt{C_d}$$

where C_d is the orifice discharge coefficient. This neglects frictional losses at the orifice, which may be

Table I. Summary and Results of Freidman and Mueller

A_f	b, ft.	C_d[a]	C_1[b]	y, ft.	A_fL/y
0.00682	0.0416	0.645	0.283	0.359	0.0385
0.00682	0.0416	0.645	0.321	0.187	0.0730
0.0123	0.0416	0.588	0.252	0.354	0.0695
0.0123	0.0416	0.588	0.283	0.187	0.1315
0.0230	0.0625	0.586	0.195	0.354	0.130
0.0273	0.0416	0.627	0.16	0.354	0.154
0.0273	0.0416	0.627	0.194	0.187	0.292
0.0273	0.0416	0.627	0.208	0.187	0.146
0.104	0.0416	0.549	0.046	0.354	0.586
0.104	0.0416	0.549	0.062	0.187	1.111

[a] C_d = orifice discharge coefficient.

[b] C_1 is defined by: $\bar{h} = C_1(G_s)^{0.78}$ B.t.u./hr. sq. ft. °F., where G_s = mass flow rate per unit area of heat transfer surface, lb./hr. sq. ft.

considered reasonable in view of the fact that, for the data used, the smallest hole diam. is 0.5 in. and the perforated plate thickness was $^1/_{16}$ in. In addition to correcting for jet contraction, the use of C_d as is done here corrects for dimensional inaccuracies of the holes in the actual perforated plates used.

The values of $\bar{h}b/k\ (U_0b/\mu)^{-0.78}$ used in forming the plots shown in Fig. 5 were obtained from the given data, using effective values of b and A_f, from the relationship:

$$\frac{\bar{h}b}{k}\left(\frac{U_0b}{\mu}\right)^{-0.78} = C_1\frac{b}{k}\left(A_f\frac{b}{\mu}\right)^{-0.78}$$

where C_1 is as defined in Table I.

Figure 5 shows, again, that the dependence of average heat transfer coefficient in y/b becomes small for values of y/b less than about 6. Again, the values of average heat transfer are seen to be larger, in the case of impingement, than they would be if air were flowing only parallel to the plate with the same velocity, as given by equation (9).

The one data point for the case where $L = 1$ ft., shown in Fig. 5, shows that a change of the factor A_fL/y from 0.1822 to 0.091 (using effective values for A_f) causes only 5% increase in average heat transfer coefficient. Also for the two points for which the effective value of $A_f = 0.0625$, $A_fL/y = 0.586$ and 1.111 for $y/b = 10.9$ and 5.8, respectively. The heat transfer for the condition of smaller y/b is still much larger than for the condition with the larger y/b value, even though the former case involves a value of A_fL/y which is twice that of the latter. Thus, even for these large values of A_fL/y, this factor appears to be of only secondary importance.

The curves of Fig. 5 provide a qualitative indication of the influence of various geometrical factors on the average heat transfer coefficient under multiple round jets. For small values of open area fraction, A_f, the average heat transfer coefficient increases rapidly and linearly with A_f. Thus, it appears that for values of A_f less than about 0.005, and with values for y/b less than about 6, the heat transfer under each jet is independent, i.e., is not influenced by the presence of the neighboring jets. Under these circumstances, increasing A_f simply has the effect of covering a proportionally larger fraction of the total heat transfer surface area with heat transfer spots.

As A_f becomes larger, the average heat transfer coefficient increases less rapidly. This may be expected by virtue of the fact that as the jets come relatively closer together the areas of high heat transfer under the separate jets begin to overlap, and part of the potential effectiveness of each jet is lost. However, in this case, a greater fraction of the total transfer surface is becoming covered by the higher heat transfer part of each jet, so that the average value still increases, up to a point, as A_f increases. In addition to the overlapping of the effective heat transfer areas, some flow interference between the jets probably occurs as A_f is increased. This interference has the effect of decreasing the local values of h under each jet, as demonstrated by the fact that as A_f increases beyond a value of about 0.2, the average heat transfer coefficient

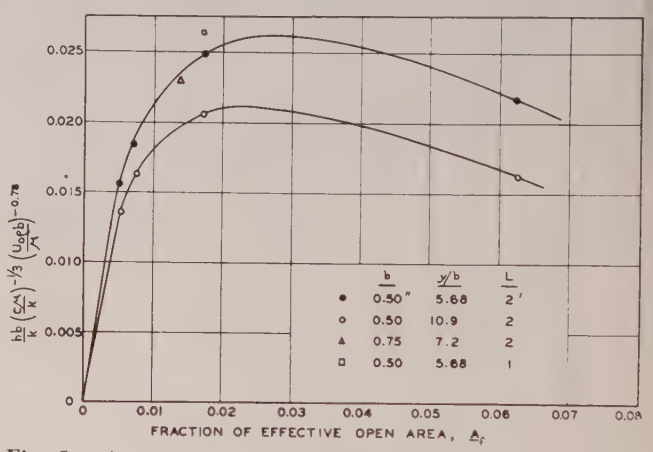

Fig. 5. Average heat transfer coefficient under multiple round jets

reaches a maximum and then decreases. The reduction in heat transfer coefficient caused by flow interference between jets is more pronounced and occurs for smaller values of A_f when the ratio y/b is larger. This may be expected from the fact that for larger values of y/b, the effective diameter of the jet is larger at the point where it approaches the surface.

AN INDEX OF PERFORMANCE FOR AIR IMPINGEMENT SYSTEMS

One of the important practical objectives of an air-impingement system is to achieve a high heat transfer rate with a minimum expenditure of air blowing power. Therefore, an index which is indicative of the heat transfer rate under conditions of constant power expenditure is an important measure of any air-impingement drier system. Such an index may be defined as follows.

The air-blowing power is proportional to the product of volume flow rate and pressure drop through the orifice. This pressure drop, in turn, is proportional to U_0^2. Thus, we can write, for two-dimensional jets:

$$P = K \frac{U_o^3 b}{X} \tag{15}$$

and for round jets:

$$P = K \frac{U_0^3 b^2}{2R^2} \tag{16}$$

where P is air-blowing power per unit area of the heat transfer surface, and K is simply a unit conversion factor.

The heat transfer coefficient varies with three types of factors; the geometrical configuration of the system, physical properties of the air, and the velocity of the jet. In particular, heat transfer coefficient varies in proportion to U_0^m, where m is an exponent having a value between 0.7 and 0.8. Using this factor together with equation (15) or (16), we may write

$$h = C_2(P)^{m/3} \tag{17}$$

where C_2 is then the index of performance, depending only on the geometrical configuration and on the physical properties of the air. Provided that all comparisons of air-impingement systems are made for the same pressure at the heat transfer surface, and approximately for the same air temperature, then the index, C_2, is an unbiased index of performance of the geometrical configuration of any air-impingement system. It is of illustrative interest to attempt to calculate values of the index of performance, C_2, for examples with two-dimensional and with round jets. Assume that in both cases, y/b is less than 3, and $b = 0.25$ in. Then, using equations (10) and (11), assuming that $m = 0.78$, and assuming that the air properties are those existing at room temperature and atmospheric pressure, we have, for two-dimensional jets, using units of ft., hr., lb., °F. and B.t.u.:

$$h = 0.048\ U_0^{0.78} \phi_2 \left(\frac{x}{b}, \frac{y}{b}\right)$$

and for round jets:

$$h = 0.048\ U_0^{0.78} \phi_3 \left(\frac{r}{b}, \frac{y}{b}\right).$$

Expressing the jet discharge velocity, U_0 in terms of unit blowing power, P, using equations (15) and (16), we get:

$$\bar{h} = 0.048\ (P/K)^{0.26} (b/X)^{1.48} \int_0^X \phi_2 d(x/b) \text{ for slots}$$

and for round jets:

$$\bar{h} = 0.115\ (P/K)^{0.26}\ (b/R)^{1.48} \int_0^R r/b \phi_3 d(r/b).$$

The curve in Fig. 3, is, in effect, a plot of ϕ_2 vs. x/b. Assuming that this curve for a single jet applies also to the case of multiple two-dimensional jets, we can evaluate the integral in the first of the two equations above by graphical integration of the curve of Fig. 3. This assumption will lead to an over-estimate of C_2, because, as a result of flow interference, the actual values of the function ϕ_2 will be smaller for multiple jets than the values shown in Fig. 3 for a single jet. The curves of Fig. 5 are, in effect, plots of the function:

$$2 \left(\frac{b}{R}\right)^2 \int_0^R \frac{r}{b} \phi_3 d \left(\frac{r}{b}\right)$$

for the case of multiple round jets. Assuming that the curve of Fig. 5 for $y/b = 5.8$ applies approximately to our example in which $y/b = 3$, we can then use it to evaluate the integral in the second of the two equations above. The results of these calculations show that, in the case of two-dimensional jets, the value of C_2 increases with A_f up to a value of

$$C_2 \text{ (slots)} = 0.00264\ (K)^{-0.26}$$

for $X/b = 45$ ($A_f = 0.011$), and then continues to increase by negligible amounts for large further increases of X/b. For the example of round jets, the value of C_2 reaches a maximum, when $R/b = 3.95$ ($A_f = 0.016$), equal to

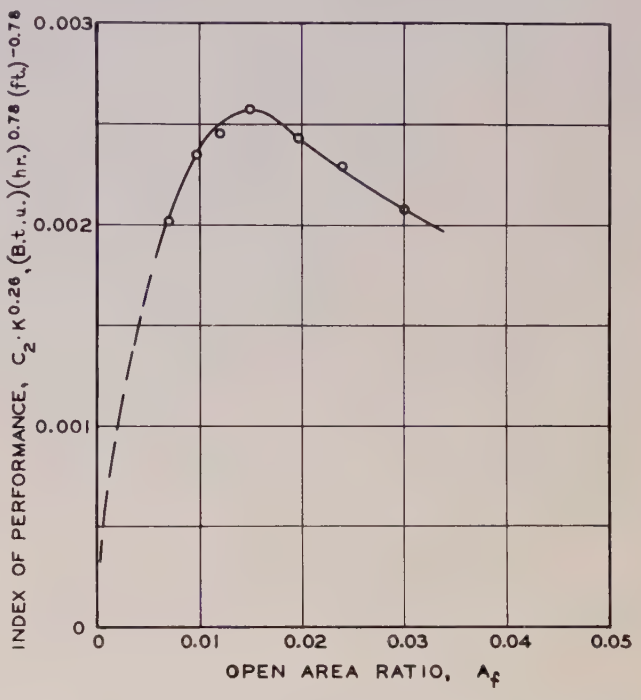

Fig. 6. Variation of the index of performance with open area ratio for multiple round jets

$$C_2 \text{ (round jets)} = 0.00285\ (K)^{-0.26}.$$

Since we have overestimated the performance index in the case of the two-dimensional jets by not including the effect of flow interference, these results support the contention, stated earlier, that the performance of round jets is better than that of two-dimensional jets, other conditions being equal.

In the process of development of air-impingement systems at Beloit Iron Works, Daane and Pantaleo (*9*), conducted a series of experiments for average heat transfer coefficient under multiple round jets. The experimental procedure was in all respects similar to that of Freidman and Mueller (*10*). In this work, the value of y was fixed at 1 in. This was considered to be a suitable compromise between the practical desire to avoid an inconveniently close spacing between the perforated orifice plate and the surface of the paper drier on the one hand, and the small heat transfer advantage of small system size on the other hand. As indicated by the previously presented heat transfer

correlation formulas and by the definition of the performance index, it may be expected that the performance index will vary approximately in proportion to $b^{-0.22}$ for a series of systems of different size but in which geometric similarity is preserved.

With the value of y fixed at 1 in., heat transfer measurements were made for several perforated plates having various values of A_f and having a series of values of hole size, b. Optimum values of b and A_f were found by direct experiment. The optimum values, leading to a maximum value of performance index, C_2, were concluded to be:

$$b = 0.375 \text{ in.}$$
$$A_f = 0.015$$

The fact that there is an optimum hole size for a given value of y may be explained on the basis that, neglecting the effect of interference between jets, the heat transfer coefficient increases with decrease in b, but the reduction in potential heat transfer due to interference becomes more pronounced as y/b increases. The existence of an optimum value of A_f for any given values of b and y has been explained by the example discussed above. It is of interest to note that the optimum value of A_f found from the experiments by Daane and Pantaleo agrees very well with the optimum value calculated for the example using the data of Freidman and Mueller. The variation of performance index, C_2 with open area ratio, A_f, as found by Daane and Pantaleo for $b = 0.375$ and $y = 1$ is shown in Fig. 6.

DRYING OF PAPER

Although a high heat transfer coefficient is essential in order to obtain rapid drying rates, other factors in addition to heat transfer coefficient determine the actual rate of drying. Drying of paper involves simultaneous heat and mass transfer accompanied by continuous changes in the fiber structure. It is a much more complex process than heat transfer to a solid surface, which we have discussed so far. The surface of paper is neither smooth nor continuous. The internal fiber structure cannot be described in detail. When heat is supplied to a newly formed sheet saturated with water, evaporation occurs initially at the surface. As the vapor moves through the boundary layer under a partial pressure difference, moisture migrates from the interior of the sheet toward the surface under a capillary pressure difference. This is conveniently referred to as surface drying. As drying proceeds, the zone of vaporization expands into the interior. While the moisture continues its movement to the vaporization zone, the vapor must now diffuse out of the sheet as well as through the boundary layer. Furthermore, heat must now be transferred into the interior of the sheet as well as through the boundary layer. Heat transfer to the interior of the sheet is primarily governed by conduction. Han and Ulmanen (*11*) have shown that the apparent conductivity of paper is a strong function of moisture content, the value being within the limits of 0.39 B.t.u./hr. sq. ft. °F./ft., which is the conductivity of water, and 0.03 to 0.1, which is the conductivity range of dry paper. The fiber structure, especially porosity, is also an important factor. When the moisture content of the sheet is reduced sufficiently, the moisture network becomes disrupted and evaporation occurs in isolated spots. The combined situation just described is called internal drying. A reliable quantitative treatment of drying rate under these conditions has not yet been attained.

When surface drying conditions prevail, such as in the drying of sheets with high moisture content, or in drying of coating and sizing, it is felt that a reasonably accurate analysis of drying rate is possible. In this case, the rate of mass transfer of vapor through the boundary layer will be proportional to the difference between the vapor pressure of the surface moisture and the partial pressure of the vapor in the air above the boundary layer. The constant of proportionality, called the mass transfer coefficient, is proportional to the heat transfer coefficient, and in fact may be calculated from the heat transfer coefficient. This fact allows the computation of drying rate under conditions of surface drying. Under these circumstances, the advantages of air-impingement drying are obvious. Not only is it possible to achieve a high heat transfer rate from a convenient heat source to the sheet surface, but the vapor mass transfer coefficient is also greatly improved as a result of the air-impingement.

Unfortunately, internal drying cannot be analyzed as simply, for reasons mentioned above. Furthermore, it should be pointed out that whether surface drying or internal drying occurs in a given situation depends not only on the moisture content, but also on the nature of the sheet and, to a large extent, on the rate of drying. At a sufficiently high drying rate, the moisture movement from the interior of the sheet to the surface may not be fast enough to maintain a saturated surface, even when the average moisture content of the sheet is fairly high.

For the purpose of more completely evaluating the effectiveness of air-impingement drying under a wider range of conditions, and in order to determine the most advantageous way in which to use air-impingement drying on a paper machine, additional experimental determinations of drying rate for various types of paper are required. Further research in the mechanisms of internal drying is also to be desired.

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Presented at the 15th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Oct. 24–28, 1960.

The authors wish to thank the management of Beloit Iron Works, Beloit, Wis., for permitting publication of this paper, which is partly based on the work done at The Institute of Paper Chemistry under the sponsorship of Beloit Iron Works.

ASSOCIATION NEWS AND EVENTS

National Conferences

1961

46th Annual Meeting, Feb. 19–23, 1961, Commodore Hotel, New York, N. Y.

Twelfth Coating Conference, May 8–10, 1961, Statler-Hilton Hotel, Buffalo, N. Y.

Lignin Symposium, Aug. 14–16, 1961, Edgewater Beach Hotel, Chicago, Ill.

Twelfth Testing Conference, Aug. 15–18, 1961, Queen Elizabeth Hotel, Montreal, Que.

Eleventh Corrugated Containers Conference, Sept. 11–13, 1961, St. Francis Hotel, San Francisco, Calif.

Fourth International Mechanical Pulping Conference, Sept. 19–21, 1961, Edgewater Beach Hotel, Chicago, Ill.

Symposium on Formation and Structure of Paper, Sept. 25–29, 1961, B.P.B.M.A., Oxford England.

Sixteenth Plastics-Paper Conference, Oct. 9–11, 1961, French Lick Sheraton Hotel, French Lick, Ind.

Sixteenth Engineering Conference, Oct. 15–19, 1961, Shoreham Hotel, Washington, D. C.

Fifteenth Alkaline Pulping Conference, Nov. 1–3, 1961, Rice Hotel, Houston, Tex.

1962

47th Annual Meeting, Feb. 18–22, 1962, Commodore Hotel, New York, N. Y.

Thirteenth Coating Conference, May 14–16, 1962, Netherland-Hilton Hotel, Cincinnati, Ohio.

Thirteenth Testing Conference, Sept. 18–20, 1962, Benjamin Franklin Hotel, Philadelphia, Pa.

Seventeenth Engineering Conference, Oct. 14–19, 1962, Queen Elizabeth Hotel, Montreal, Que.

Twelfth Corrugated Containers Conference, Oct. 23–26, 1962, Statler-Hilton Hotel, Boston, Mass.

Sixteenth Alkaline Pulping Conference, 1962, Savannah, Ga.

1963

Fourteenth Coating Conference, May 19–22, 1963, French Lick Sheraton Hotel, French Lick, Ind.

Thirteenth Corrugated Containers Conference, Oct. 22–25, 1963, Statler-Hilton Hotel, Detroit, Mich.

Eighteenth Engineering Conference, 1963, Chicago, Ill.

Other Association Meetings

The German Association, Verein der Zellstoff und Papier Chemiker und Ingenieure, will hold its annual meeting in Baden-Baden, June 27–30, 1961.

Annual Meeting Personnel Service

To assist companies recruiting technical men in publicizing their personnel needs, a "Personnel Service" room will be provided at the Hotel Commodore during the 1961 Annual Meeting. Company members of the Association may post descriptions of their openings in this room which will be available to all delegates. This service was initiated at the 1959 meeting and is being repeated at the request of the companies which participated.

Interested corporate and sustaining members are asked to forward brief position descriptions to the Association office by Feb. 13, 1961. These descriptions will be displayed on bulletin boards in the "Personnel Service" room on Monday through Wednesday, February 20–22. These descriptions should include the name and address of a company representative who may be approached if additional information or an interview is desired. Companies planning to have a personnel representative at the Annual Meeting may add his name and hotel room number to the description after he has arrived in New York. If the position descriptions of any one company cover more than a single sheet, the subsequent pages will be posted behind the first sheet on the bulletin boards.

The Association's role in this activity is expressly limited to providing the area to its company members without charge, supplying an attendant, and publicizing the location of the room in the program booklet and on the conference bulletin boards.

Twelfth Coating Conference

The dates of the Twelfth TAPPI Coating Conference which will be held at the Statler-Hilton Hotel, Buffalo, N. Y., have been moved forward to May 8 through 10. This change of dates was necessary in order to accommodate all those planning to attend the conference.

The meeting will be under the guidance of the following chairmen:

General Conference Chairman—R. W. Martinek, Kimberly-Clark Corp., Neenah, Wis.
Technical Program Chairman—C. G. Whelpton, Champion Paper and Fibre Co., Hamilton, Ohio
Publicity Chairman—W. E. Welliver, Mineral & Chemical Philipp Corp., Menlo Park, N. J.
Local Arrangements Chairman—C. E. Mikel, Corn Products Sales Co., Buffalo, N. Y.
Registration Chairman—W. I. Arnold, International Paper Co., North Tonawanda, N. Y.
Mill Tours Chairman—R. S. Buckley, Lockport Felt Co., Newfane, N. Y.
Hotel Arrangements Chairman—S. F. M. Maclaren, Penick-Ford Ltd., Inc., Buffalo, N. Y.

As of this date the following program and mill tours have been confirmed, while other papers and tours are still in the firming-up stage:

PANEL—"ADHESVIES FOR COATINGS"—*Tuesday Morning, May 9*

Moderator—Richard T. Trelfa, Perkins-Goodwin Co.
Panelists—Frederick H. Frost, S. D. Warren Co.; Frank M Kaulakis, Consolidated Water Power & Paper Co.; J. T. Loomer, Continental Can Co.; William P. Taylor, The Champion Paper & Fibre Co.

PAPERS

"The Use of Polyvinyl Alcohol as a Color Coating Adhesive" by George P. Colgan, Air Reduction Chemical Co.
"Adhesion to Fibrous Materials" by Prof. J. J. Bikerman, Massachusetts Institute of Technology.
"Cationic Latex with Controllable Penetration and Set-Off Properties" by E. J. Heiser, Dow Chemical Co.
"Precast Clay Coating—a New Process and a New Product" by Frank D. Bergstein, Interstate Folding Box Co.
"Kohler Coater" by John R. Gunning, Provincial Paper Sect., Abitibi Power & Paper, and F. W. Kohler, Kohler Coating Machinery Corp.
"The Requirements of Starch for Paper Coating" by A. Harsveldt, Nationale Zetmeelindustrie.
"Rheology Modifiers for Trailing Blade Coasters" by James F. Hern, Nopco Chemical Company.
"Coating Forecast" by Maurice R. Castagne, *Pulp & Paper*.
"Starch Graft Copolymers as Paper Coating Adhesives" by M. L. Cushing, A. E. Staley Mfg. Co.

MILL TOURS—*Tuesday Afternoon, May 9*

International Paper Co., North Tonawanda, N. Y.
Lockport Felt Co., Newfame, N. Y.
J. W. Clement Printing Co., Buffalo, N. Y.

It is suggested that hotel reservations be made immediately with the Statler-Hilton Hotel, Buffalo, N. Y.

National Symposium on Pulp and Paper Instrumentation

The Instrument Society of America and TAPPI are co-sponsors of the National Symposium on Pulp and Paper Instrumentation to be held May 10–12, 1961 at the Northland Hotel in Green Bay, Wis. Cooperating in this symposium is TAPPI's Process Instrumentation Committee E. W. Prince, Champion Paper and Fibre Co., Hamilton, Ohio, Chairman: the Fox River Valley Section of ISA., P. M. Giesler, Charmin Paper Products Co., Green Bay, Wis., chairman, and the Lake States Section of TAPPI, W. R. Nelson, Green Bay Pulp and Paper Co., Green Bay, Wis., chairman.

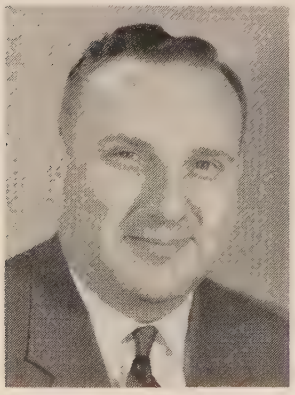
G. G. M. Eastwood, Kimberly-Clark Corp., Neenah, Wis., is the general symposium chairman. Mr. Eastwood is also vice-chairman-designate of the TAPPI Process Instrumentation Committee.

Other positions and personnel of the Symposium Committee are as follows:

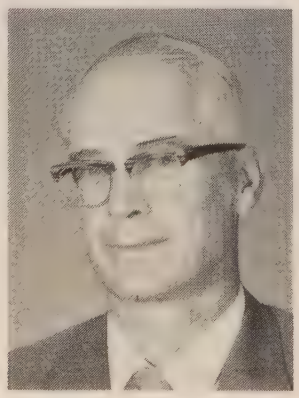
Secretary—P. M. Giesler, Charmin Paper Product Co., Green Bay, Wis.
Finance—H. O. Teeple (Treasurer), TAPPI, New York, N. Y., H. S. Kindler, ISA, Pittsburgh, Pa.
ISA Section Host—P. M. Giesler, Charmin Paper Products Co., Green Bay, Wis.
TAPPI Section Host—R. L. Leaf, Shawano Paper Mills, Shawano, Wis.
Technical Program—J. W. Replogle, Jr. (for ISA), Panellit Service Corp., Skokie, Ill.; C. D. Lindwall (for TAPPI), Marathon Div., American Can Co., Menasha, Wis.
Documentation—H. S. Kindler, ISA, Pittsburgh, Pa.
Publicity—H. O. Teeple, TAPPI, New York, N. Y.
Local Publicity—D. Johnson, Mason, Neilan Co., Appleton, Wis.
Registration—J. Restle, Appleton Coated Paper Co., Appleton, Wis.
Hospitality—W. R. Nelson, Green Bay Pulp and Paper Co., Green Bay, Wis.
Hotel Arrangements—M. Schreiner, Foxboro Co., Foxboro, Mass.
Printing—H. O. Teeple, TAPPI, New York, N. Y.
Clinic—E. Kehoe, Marathon Div., American Can. Co., Menasha, Wis.; L. Clouse, Kimberly-Clark Corp., Neenah, Wis.

Messrs. Replogle and Lindwall are planning a technical program which will feature outstanding experts in pulp and paper mill instrumentation. In addition to the technical sessions, plans are being made to include a workshop and a clinic.

The tentative program is as follows:



P. M. Giesler, Paper Products Co.



G. G. M. Eastwood, Kimberly-Clark Corp.

Restle *Tuesday*—May 9, 3:00–6:00 p.m. Registration

Restle *Wednesday*—May 10, 8:00–10:00 a.m. Registration

Wednesday—May 10

Replogle	10:00	Keynote Adress
	11:00	Address
	12:00	Lunch
	1:30–4:30	Panel—Comparison of instrumentation systems
Replogle	A—Installation techniques	
	B—Costs of various installations	
	C—Preventive vs. shutdown maintenance	
Lindwall	1:30–4:30	Management workshop (by invitation)
	Evening discussion periods—details to be announced	

Thursday—May 11

Replogle	9:00–12:00	Mill instrument education panel
	12:00	Lunch
	1:30–4:30	TAPPI papers
Lindwall	A—Draw speed	
	B—pH Control	
	C—Bleach Plant	
Nelson	6:00–7:00	Cocktails
Nelson	7:00	Banquet Speaker: L. R. Theismeyer, Pulp and Paper Research Institute of Canada, Montreal, Que.

Friday—May 12

Replogle	9:00–11:30	Computor & Information System Panel
Kehoe	9:00–11:30	Maintenance clinic
Clouse	1:30–4:30	Maintenance clinics
	1:30–4:30	Mill Tours

Saturday—May 13

9:00–11:30	Maintenance clinic
1:30–4:30	Maintenance clinic

Registration fees will be:

	Members	*Nonmembers*
Symposium	$15.00	$20.00
Maintenance Clinic	2.00	3.00

Messrs. Kindler and Teeple are advisors to the Symposium for ISA and TAPPI, respectively.

Those desiring to secure hotel accommodations for the Symposium should write to "Instrumentation," Northland Hotel, Green Bay, Wis. and state date and time of both arrival and departure.

TAPPI-ASTM Technical Committee on Petroleum Wax

The TAPPI Wax Testing Committee is meeting February 8–10, inclusive, with ASTM D-2 at the Benjamin Franklin Hotel, Philadelphia, Pa. The schedule of meetings for the sections is as follows:

Wednesday, Feb. 8	Franklin Room
9–12 a.m.	Section I—Physical Properties
1–5 p.m.	Section II—Chemical Properties
Thursday, Feb. 9	Washington Room
9–12 a.m.	Section III—Functional Properties
2–4 p.m.	Section IV—Nomenclature and Specifications
4–5 p.m.	General Meeting

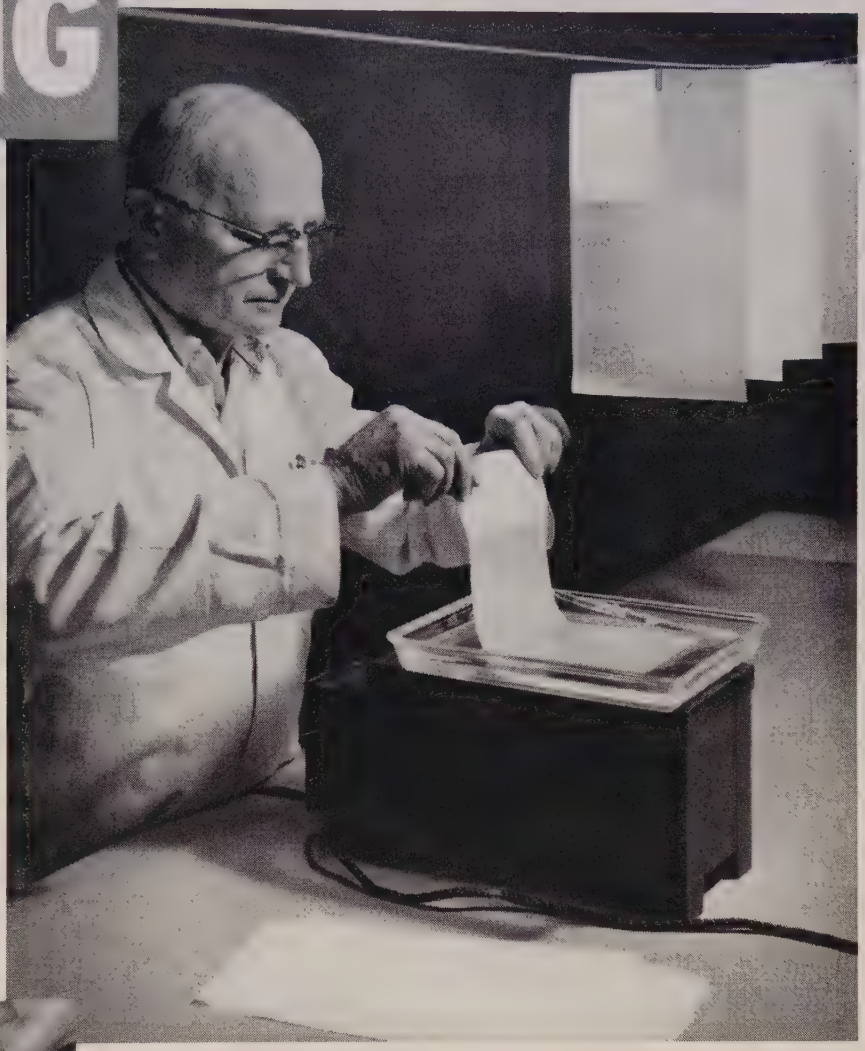
The Advisory Committee will meet Friday morning at 9–10 a.m. in Valley Forge Room A unles Mr. Dannenbrink calls it earlier for special reasons.

Packaging Course

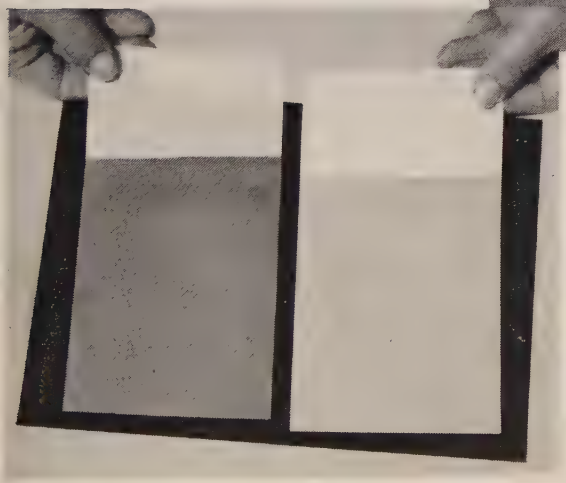
The Bernard Baruch School of the City College of New York, 23rd St. and Lexington Ave., will again offer this term a credit course entitled "Industrial Packaging." The course, to be presented in fifteen 2-hr. sessions, begins in February. The lecturer for this course will be Jerome J. Kipnees, a member of the Society of Packaging and Handling Engineers (SPHE) and TAPPI. Mr. Kipnees is secretary of the TAPPI Container Testing Committee.

From the Paper Research Laboratory of The New Jersey Zinc Company
ONE of a Series of Test Procedures on Horse Head Titanium Dioxide

WAXING



Pigmented and unpigmented handsheets are dipped in molten wax and evaluated for opacity, brightness and other properties essential to modern high grade papers for use in food packaging.



Comprehensive studies on the effect of titanium dioxide on opacity and brightness of waxed papers for food packages are an important phase of the research activities at the paper laboratory of The New Jersey Zinc Company.

Such investigations involve the preparation of handsheets in various weights—pigmented and unpigmented—the application of commercial wax coatings, and extensive evaluations for opacity and brightness.

The development of new knowledge on the advantages of Horse Head titanium dioxides in paper products is a prime objective of New Jersey Zinc research. It represents a continuing program. May we tell you more about it?

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Mr. Kipnees is vice-president-package engineering of Atlantic Gummed Paper Corp., and was formerly vice-president of Container Laboratories Inc.

Maurice A. Burnston, a member of the National Staff of TAPPI, and a vice-president of SPHE, will also serve as a lecturer. Both lecturers have previously participated in several university packaging courses.

Agricultural Fibers Committee

General

A meeting was called by A. D. Meighen, chairman, Agricultural Fibers Committee, Pulp Manufacture Division, TAPPI, to receive and discuss the reports of the Membership, Steering and Nominating Subcommittees recently appointed by Mr. Meighen in connection with the reorganization of the Agricultural Fibers Committee. The meeting was held on Nov. 10, 1960 at the Northern Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture, Peoria, Ill.

Introductory Remarks

Mr. Meighen pointed out that he, as chairman of the Agricultural Fibers Committee, has appointed the following subcommittees for the purpose of implementing the revitalization of the Agricultural Fibers Committee which has lost its initiative because of the shift in this country from straw as a fibrous raw material to wood. The subcommittees are:

Membership Committee: T. F. Clark, chairman, Northern Utilization Research, & Development Division; L. E. Eberhardt, The Bauer Brothers Co.; R. E. Shook, Sprout-Waldron & Co.
Steering Committee: E. R. Gremler, chairman, The Black-Clawson Co.; F. B. Grunwald, Consolidated Paper Co.; C. J. Wynstra, Packaging Corp. of America
Nominating Committee: J. E. Atchison, chairman, Parsons & Whittemore, Inc.; R. F. Burns, Jr., The Weston Paper & Manufacturing Co.; G. C. Baron, Consolidated Paper Co.

Also at this time Mr. Meighen mentioned with regret that his and Mr. Burn's firm, The Weston Paper & Manufacturing Co., were converting from straw to wood pulping and that, therefore, their interest in the near future would be mainly as observers. However, Mr. Meighen expressed the desire to follow through on the reorganization of the committee which he felt could serve a most useful purpose in TAPPI on the basis of the widespread interest in fibers other than wood fibers, even though straw had practically lost its place in this country as a fibrous raw material. In this connection Mr. Barron mentioned that his firm, The Consolidated Paper Co., was thinking seriously of converting to the manufacture of bogus corrugating board in place of strawboard. It was also mentioned that the strawboard mill at Saskatoon, Canada, was also giving up straw pulping. Thus, the only user of straw appears to be the Packaging Corp. of America, Quincy, Ill.

Discussion and Reports of Subcommittees

Scope of the Agricultural Fibers Committee. The following statement of scope was suggested by Mr. Meighen:

> "The processes of selecting, harvesting, preparing, and pulping agricultural, annual, and similar fibrous materials other than wood; the subsequent chemical recovery, washing, screening, and thickening prior to stock preparation."

This statement of scope is in line with the similar statements of other committees of the Pulp Manufacture Division.

During the course of the meeting it was realized that the statement above did not cover precisely the probable objectives of the committee and that a revision would be in order. Suggestions are to be made to the chairman in time for presentation at the annual meeting in New York in February, 1961.

The possibility of increasing the scope of the committee's activities to include man-made fibers was discussed. However, it was learned subsequently that a Synthetic Fibers Committee was being formed in the Converting and Consuming Division.

Membership Committee Report. Mr. Clark put forward a list of some 125 names which he and his committee had listed as possibilities for membership on the committee. Many of these names were TAPPI members from foreign countries where the fibrous materials that are now of interest to the committee are widely used. However, it was agreed that the basic working body of the Agricultural Fibers Committee should be constituted from U. S. members. It was pointed out that a nucleus for the committee did, in fact, exist in the form of the present subcommittees and several of the members of the "former" Agricultural Fibers Committee.

Applications for membership on the Agricultural Fibers Committee will be gratefully received by T. F. Clark.

The interest and actual use of fibrous materials other than wood in the United States was pointed out as having considerable diversity. There is bagasse used in this country and, of course, there is the great interest in bagasse in Hawaii, our new state. There is the long existence in the successful use of flax by the cigaratte paper manufacturers. There is the use of old rope to give manila hemp and other long fibers in a number of mills in the east. There is also the importation of esparto and other fibers for use in certain mills. These are examples of segments of the industry which can be drawn on for membership. The Membership Committee will solicit membership from individuals and firms based on a screening of the long list of names presented at this meeting.

Steering Committee Report. The objective of the Steering Committee was to prepare suggestions on projects which would be suitable for activities for the new Agricultural Fibers Committee. The following suggestions of projects were agreed on as being suitable for activities of the Committee:

1. A survey of the applications of fibers used for pulp and paper in the United States and their characteristics.
2. An evaluation of the suitability of annual and similar fibrous material for the United States pulp and paper industry.
3. A compilation of literature relating to fibrous material falling within the scope of the Agricultural Fibers Committee.
4. American practices of receiving, storing, and preparing prior to processing of new and similar fibers.
5. Investigation of treatment methods to adapt specific fibers to papermaking technology.

Projects will be chosen from the list above at the annual meeting in New York, February, 1961. Additional projects may be included in the list as may be suggested.

1961 Annual Meeting Program. It is planned to have a complete meeting of the Agricultural Fibers Committee in New York at the annual meeting, February, 1961. A committee meeting will be held on the afternoon of Monday, February 20, and a 3-hr. technical session will be held on Wednesday afternoon, February 22. These times have been requested from National TAPPI.

The dates established by TAPPI Headquarters for the submission of the titles and authors of the papers, the abstracts, and the manuscripts will be observed.

The following possibilities for technical papers for the 1961 meeting were outlined:

1. A paper by Dr. Robert E. Perdue, Plant Industry Station, U. S. Department of Agriculture, Beltsville, Md., on fiber measurements of crop fibers. This paper can be considered a firm committment.
2. A paper on kenaf by T. F. Clark from the Northern Utilization and Research Division, U.S.D.A., Peoria. This is also a firm commitment for the program.
3. The Black-Clawson Co. has offered one of two papers:
   a. A paper on continuous pulping of a number of annual and similar fibers with special reference to applications in countries outside of the United States.
   b. A paper on developments in pulping of annual and similar

*Idea submitted by Robert F. Chase, Franconia Paper Corp., Lincoln, N. H.

Photo by: Ewing Galloway, N. Y.

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"What famous place reminds you of Hamilton Felts? Tell us why in a few words; sign your name and address and name of company. Each month, the idea from a U.S. papermaker that we use wins a new 1961 model Shakespeare Spincast Rod and Reel—FREE! When identical winning ideas are submitted by 2 or more papermakers, the one with the earliest postmark will be considered the winner. *Every U.S. papermaker entrant* receives a famous Rex Spoon fishing lure—FREE. Send me your suggestion—today. Ham Feltz, Dept. T, 612 First National Bank Bldg., Cincinnati 2, Ohio."

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fibers in the Iron Curtain countries, based on the published research and other activities.

4. A paper on pulping, bleaching, and papermaking of esparto from Parsons & Whittemore, Inc. This is also a firm commitment.

5. Papers will be immediately solicited from several leading United States pulp manufacturing firms who have been active in this field.

It was felt that there should be a minimum of four papers available and it would be desirable to have more from which to select the program.

Nominating Committee. The report on the nominations for those to be elected at the 1961 meeting in February was read by R. F. Burns, Jr. in the absence of J. E. Atchison. The present vice-chairman, T. F. Clark, will head the nominations as the recommendation for chairman of the committee. Normally it has been the practice of the committee for the vice-chairman to move to the chairmanship and the secretary to move to the vice-chairman spot for later elevation to the chairman position. In view of the changed objectives of the committee, it is now necessary to nominate both a new secretary and a new vice-chairman. A number of names were screened from the membership list presented by the Membership Committee and these names will be submitted to the chairman of the Nominating Committee, J. E. Atchison, for consideration and preparation of a complete suggested list of nominees for the three offices of the committee.

Name of the Committee. During the course of the Peoria meeting there were expressions of doubt whether the present name of the Agricultural Fibers Committee now suited the new objectives and activities. The term "Agricultural" does not describe many of the fibrous materials now within the scope of the Committee's activities. The term "Nonwood" fibers was felt to be too negative an expression. The term "annual" was also felt to be inadequate to describe all the fibers. However, no suitable term was developed and it was decided that, for the time being, the name would remain the same. However, suggestions for a change in the name are in order for consideration at the 1961 New York meeting.

J. N. McGovern

Eleventh Coating Conference

The Eleventh Coating Conference of the Technical Association of the Pulp and Paper Industry was held May 23–25, 1960, at the Edgewater Beach Hotel, Chicago, Ill. The conference is sponsored annually by the Association's Coating Committee of the Coating and Graphic Arts Division. J. E. Wilber, St. Regis Paper Co., Deferiet, N. Y., and R. T. Trelfa, Perkins-Goodwin Co., New York, N. Y., respectively are chairmen of the sponsoring committee and division.

The attendance of 957 conferees made this by far the largest TAPPI coating conference to date, and the largest of all TAPPI functional conferences. The program included four half-day technical sessions, a panel discussion, the annual luncheon, and plant tours as well as meetings of the Coating Committee and several of its subcommittees and task groups.

In the following report, brief abstracts of the papers are given. The full text of all the papers appears in various issues of *Tappi*.

The conference was planned by the following committee under the general chairmanship of R. W. Hagemeyer, Wyandotte Chemicals Corp., Wyandotte, Mich.

R. W. Martinek, Kimberly-Clark Corp., Neenah, Wis., program chairman
W. E. Welliver, Minerals & Chemicals Corp. of America, Menlo Park, N. J., publicity chairman
C. W. Cairns, Dow Chemical Co., Midland, Mich., Local Arrangements chairman

Program Committee

R. I. Bashford, Jr., Penick & Ford Ltd., Inc., Dayton, Ohio
H. J. Connell, S. D. Warren Co., Cumberland Mills, Me.

Coating Council Meeting: R. W. Martinek, Kimberly-Clark Corp.; C. A. Morton, Alden Press; C. G. Landes, North Carolina State College of Agriculture and Engineering; A. W. Winchester, TAPPI; R. W. Hagemeyer, Wyandotte Chemicals Corp.; F. Kaulakis, Consolidated Water Power & Paper Co.; J. E. Wilber, St. Regis Paper Co.; C. G. Whelpton, Champion Paper & Fibre Co.

L. A. Gilbertson, Marathon Div., American Can Co., Neenah, Wis.
H. R. Hall, Allied Paper Corp., Kalamazoo, Mich.
H. H. Lavery, International Paper Co., Corinth, N. Y.
A. W. Neubauer, Crown Zellerbach Corp., Camas, Wash.
E. R. Padavic, Container Corp. of America, Santa Clara, Calif.
P. W. Plante, St. Regis Paper Co., Deferiet, N. Y.
C. A. Richardson, Blandin Paper Co., Grand Rapids, Minn.
C. G. Whelpton, Champion Paper & Fibre Co., Hamilton, Ohio
J. H. Wing, Continental Can Co., Inc., Robert Gair Paper Prod. Group, Uncasville, Conn.
J. T. Goodwin, Jr., Corn Industries Research Foundation, Inc., Washington, D. C.

Local Arrangements Committee

R. A. Olson, Central Soya Co., Inc., Chicago, Ill.
H. J. Klauke, Container Corp. of America, Chicago, Ill.
J. M. Prescott, Velsicol Chemical Corp., Chicago, Ill.
A. Glassman, R. R. Donnelly & Sons Co., Chicago, Ill.
M. W. Snover, Hollingsworth & Vose Co., Chicago, Ill.

First Session

The conference was opened on Monday, May 23, after an early morning Coating Committee meeting, by J. E. Wilber, Coating Committee chairman, and R. W. Martinek, program chairman. The meeting was then turned over to L. A. Gilbertson, Marathon Div., American Can Co., Neenah, Wis., who was chairman of the first technical session. Abstracts of the two papers presented during this session are given below.

"New Surface Sizing Technique with Polyvinyl Alcohol," by B. A. Beardwood and E. P. Czerwin, E. I. du Pont de Nemours and Co., Inc., Wilmington, Del. Widespread application of polyvinyl alcohol as a surface size for paper and paperboard has been limited in the past because solutions of polyvinyl alcohol penetrate too deeply into paper and paperboard. A new surface sizing technique has been developed which uses a pretreatment of borax solution to gel "Elvanol"* polyvinyl alcohol sizes on the surface of the sheet, thus preventing excessive penetration of the size. The two-stage borax/polyvinyl alcohol sizing technique has been evaluated on several types of paper and paperboard in laboratory studies and in mill trials. On all substrates the borax/polyvinyl alcohol size demonstrated excellent resistance to mineral oil penetration and improved resistance to turpentine penetration.

In the laboratory the borax/polyvinyl alcohol size was com-

* Elvanol is du Pont's registered trademark for its polyvinyl alcohol.

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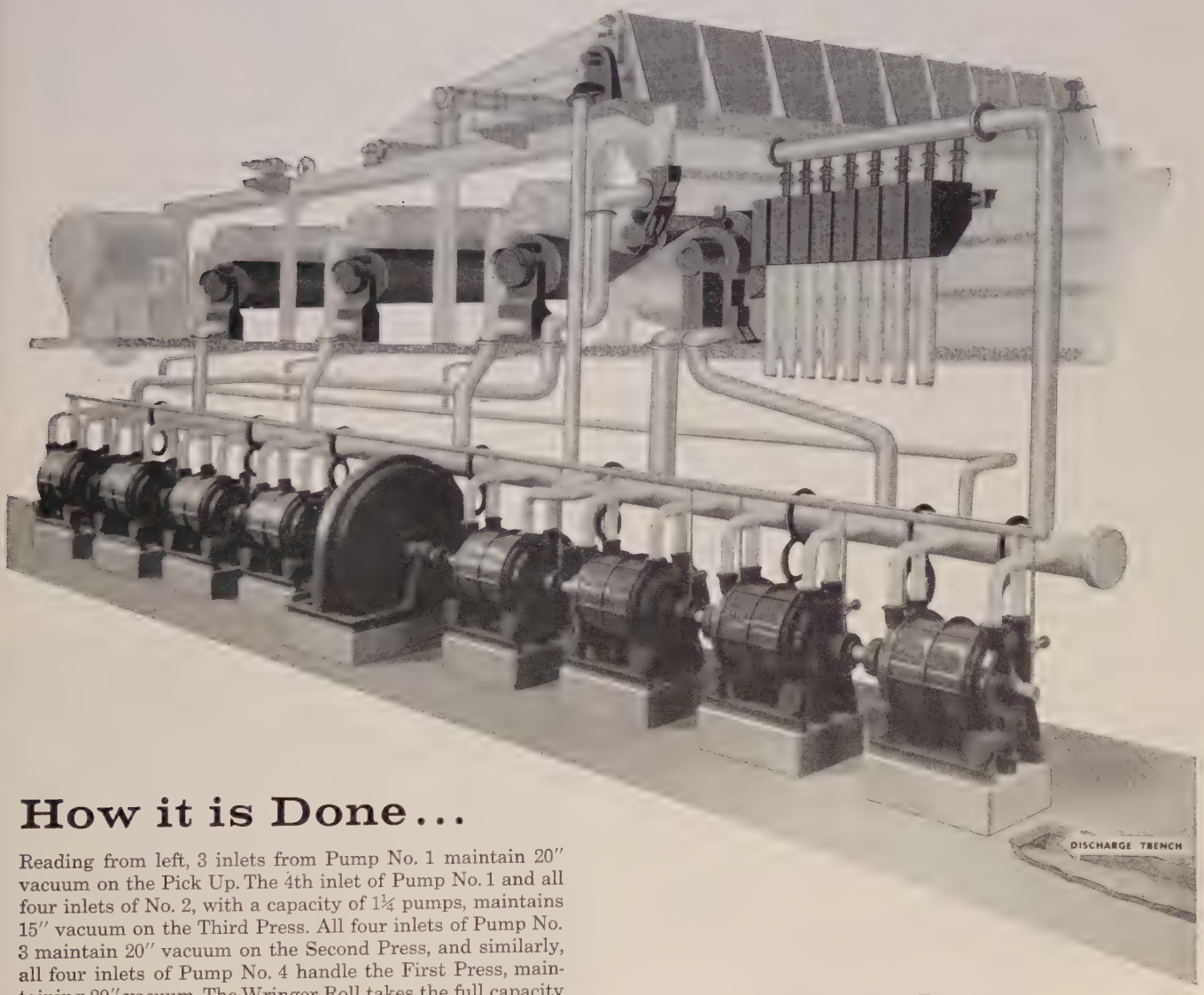

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Reading from left, 3 inlets from Pump No. 1 maintain 20″ vacuum on the Pick Up. The 4th inlet of Pump No. 1 and all four inlets of No. 2, with a capacity of 1¼ pumps, maintains 15″ vacuum on the Third Press. All four inlets of Pump No. 3 maintain 20″ vacuum on the Second Press, and similarly, all four inlets of Pump No. 4 handle the First Press, maintaining 20″ vacuum. The Wringer Roll takes the full capacity of Pump No. 5, requiring 10″ vacuum. The High Vacuum Couch Box takes a pump and a half, 4 inlets of Pump No. 6, and two inlets of Pump No. 7, maintaining 20″ vacuum. The remaining two inlets of Pump No. 7 maintain 10″ vacuum on the Low Vacuum Couch Box. Only one inlet of Pump No. 8 is required to handle the Felt Conditioners at 10″ and the remaining three inlets of Pump No. 8 handily maintain 10″ vacuum on the Wire Boxes.

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First Session: L. A. Gilbertson, American Can Co.; B. A. Beardwood, E. I. du Pont de Nemours & Co., Inc.; E. P. Czerwin, E. I. du Pont de Nemours & Co., Inc.; W. L. Boyer, Firestone Plastics Co.; A. Glassman, R. R. Donnelly & Sons; W. C. Walker, West Virginia Pulp & Paper Co.

pared on an equal cost basis to other sizes including straight polyvinyl alcohol starch, sodium carboxymethylcellulose, and sodium alginate. Unbleached kraft linerboard was used as the substrate in this study. The sized linerboard was tested for oil absorption, IGT printability, water absorption, and bursting strength. The borax/polyvinyl alcohol size resulted in superior oil holdout and was comparable to the other sizes in the other properties treated.

"Coating Polymers for Paper Products," by W. L. Boyer, Firestone Plastics Co., Pottstown, Pa. Finished paper products frequently depend on coatings for consumer acceptance. Manufacturers and converters are often limited in their adaption and application of many coating polymers because of the time required to learn the backgrounds of these polymers. Fortunately, the practical utilization of these polymers requires only a basic understanding of their relationship to each other, rather than details of their complex chemical composition. All coatings are based on film forming polymers which can be compared, for practical purposes, as simply as we compare the families of living things. Identification of all polymers with their "clans" is the first big step in determining their optimum application.

All polymers fall into just two general classifications—thermoplastic or thermosetting. Both of these branches of the polymer family have had many new "offspring" in the last few years and undoubtedly this is only the beginning of their population increase. Almost all paper coating polymers, old timers as well as the newer ones, fall in the thermoplastic branch of the family.

Most of the new thermoplastic polymers are made through a unique process called polymerization. Polymerization is simply the linking of one (monomer) chemical unit to another to form a link chain of many units (polymer). These "vertebra" chains are much the same chemically, but their length, branches, and appendages, determine their tremendous differences. Members of just one "vertebra family" often appear to be unrelated, because of the large variety of finished products they can produce.

This presentation of the polymer families can become a "mental index" to help catalog the polymer coatings of the past and present—and future. This "index" may help to keep the many new materials from being overlooked and forgotten, in our never ceasing efforts to obtain the best possible product, for the price our customers will pay.

Following the two papers, A. Glassman, R. R. Donnelly & Sons, Chicago, Ill., presented a report on *TAPPI Committee Project No. 130, Surface Strength Evaluation.* This project, for which TAPPI funds have been appropriated to carry out work at Lehigh University, is aimed at the development of a reliable procedure for predicting surface strength on the press. A full report will be published when the work is completed.

Second Session

A. W. Neubauer, Crown Zellerbach Corp., Camas, Wash., was chairman of the second technical session comprising four papers, abstracts of which follow.

"European Approach to Printability Research," by M. C. Rogers, Chicago Paper Testing Laboratory, Chicago, Ill. Printability research has received much attention throughout the United States and Europe in recent years. The European workers with their enviable attitude toward fundamental and semifundamental work, have approached printability in an interesting manner. Much of their work deals primarily with the surface and internal character of the paper sheet, with little attention given to the complications of runnability sometimes considered an important part of printability considerations in the United States. Their influence on the attitudes of United States graphic arts research workers is being shown by the increasing number of printability papers published by Institute laboratories. Ink transfer, printing pressures, "ink receptivity," compressibility, and capillarity are all part of the printability problem which have received extensive attention.

The European laboratories, each of which is staffed with good qualified scientific talent, are devoting major efforts to the fundamentals underlying the uses of paper as a printing medium. This is true of paper laboratories as well as those devoted to graphic arts research and development. The nature of industry and government support given to the European researcher, tends to encourage his devotion to fundamental and semicommercial aspects of a problem, undisturbed by the pressures of "something practical" being applied as is usually the case with the worker in the United States.

Like his United States counterpart, the European researcher is not able to develop a satisfactory and inclusive definition of "printability."

"New Developments in Offset Printing," by M. Bruno, Lithographic Technical Foundation, Chicago, Ill. A number of developments in lithography have helped reduce the number of paper complaints, especially coated paper, and narrowed the gap between the requirements for letterpress and

Second Session: A. W. Neubauer, Crown Zellerbach Corp.; M. C. Rogers, Chicago Paper Testing Lab.; M. Bruno, Lithographic Tech. Found.; R. E. Weber, Kimberly-Clark Corp.; N. Millman and J. B. Whitley, J. M. Huber Corp.

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Panel: P. W. Plante, St. Regis Paper Co.; L. R. Ayers, Continental Can Corp.; C. H. Borchers, Lithographic Tech. Found., Inc.; F. W. Goetz, Publication Corp.; M. C. Rogers, Chicago Paper Testing Lab.; W. W. Roehr, Kimberly-Clark Corp.; A. P. Reynolds, S. D. Warren Co.; W. I. Stinger, Marathon Div., American Can Corp.

offset coated papers. Very important ones have been the improvements in plates and presses which have made it possible to print with much less water. New developments under investigation now show promise of narrowing the gap still further. These are (1) the Dahlgren dampening system, which allows the use of softer inks and even less water, and (2) a new disposable blanket which is more compressible than conventional rubber blankets and prints with less slur. Other means of eliminating paper complaints are by the development and use of instruments and techniques for pretesting papers before they go to press. Ink transfer studies at the Lithographic Technical Foundation and other laboratories will help by providing information on the exact requirements of papers for optimum transfer.

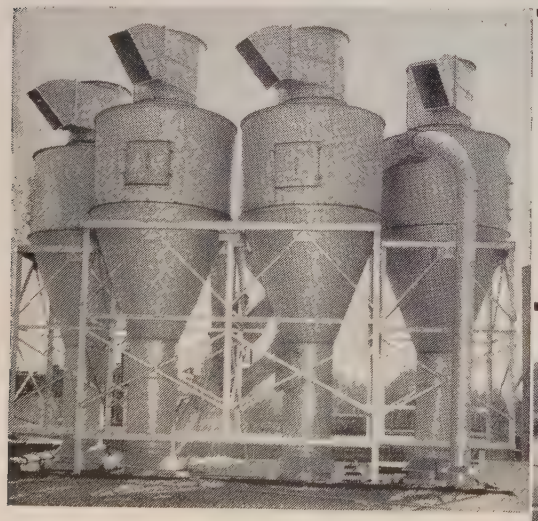
"The Effect of Pigment Binders on Paper Gloss, Printed Gloss, and Oil Absorption," by R. E. Weber, Kimberly-Clark Corp., Neenah, Wis. This report is a study of the interrelationships of paper gloss, printed gloss, and oil absorption as it pertains to the adhesive concentration in paper coatings. The various adhesives studied along with a clay pigment are: (1) hydroxyethylated acid modified cornstarch, (2) corn white dextrin, and (3) soy protein. These coatings were applied by KCM roll coater.

The results show that printed gloss and oil hold-out are improved with increased adhesive concentrations. Maximum printed glosses and oil hold-out were reached at 36 and 45% adhesive concentrations, respectively (based on a weight ratio of adhesive to 100 parts of pigment) for the hydroxyethylated starch, soy protein, and white dextrin. At higher adhesive concentrations there were no changes in the above properties.

The calendered paper glosses were found to decrease at increased adhesive concentrations. Minimum glosses were found to exist at the binder levels where the maximum levels of printed gloss were obtained. At higher adhesive concentrations, the calendered paper glosses were found to increase.

The above findings are explained in terms of the void volume concept for pigments and by the varying degrees of adhesive bonding.

"The Effect of Mixing Intensity on the Dispersion of Coating Pigments in Water," by N. Millman and J. B. Whitley, J. M. Huber Corp., Huber, Ga. Dry pigments differ in their aggregative properties and consequently in their resistance to dispersion. Since the type and magnitude of the forces which maintain aggregates vary in different



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materials, the energy intensity factor required to produce dispersion can be expected to vary with each pigment. The paper describes the behavior of the principal coating pigments (clays, calcium carbonate, and titanium dioxide) in aqueous suspensions when such systems are subjected to varying rates of work. The effect of such factors as mixing intensity, mixing time, and pigment concentration on the breakdown of pigment aggregates is shown. Changes in the physical properties of the suspension as a result of mixing intensity are also discussed.

Panel Discussion

The third technical session, held Tuesday morning, May 23, took the form of a panel discussion "Coating for Printing" under H. H. Lavery, International Paper Co., Corinth, N. Y., chairman, and W. Roehr, Kimberly-Clark Corp., Neenah, Wis., Moderator. The panelists and the subjects of their presentations were as follows:

Graphic Arts Panelists

L. R. Ayers, Continental Can Corp., Inc., Robert Gair Paper Products Group, Elkhart, Ind., "Coated Board Printing."
C. H. Borchers, Lithographic Technical Foundation, Inc., Chicago, Ill., "Offset Printing."
F. W. Goetz, Publication Corp., New York, N. Y., "Rotogravure Printing."
M. C. Rogers, Chicago Paper Testing Laboratory, Chicago, Ill., "Letterpress Printing."

Coating Panelists

A. P. Reynolds, S. D. Warren Co., Cumberland Mills, Me., "Offset Printing."
W. W. Roehr, Kimberly-Clark Corp., Neenah, Wis., "Letterpress and Rotogravure Printing."
W. I. Stinger, Marathon Div., American Can Corp., Neenah, Wis., "Coated Board Printing."

Fourth Session: C. A. Richardson, Blandin Paper Co.; F. W. Holt, Brown Bridge Mills, Inc.; C. Lorenz, Black-Clawson Co., Dilts Div.; R.B. Reif, Battelle Memorial Institute; E. D. Jones, Crossett Paper Mills; N. H. Laughrey, Black-Clawson Co., Dilts Div.; F. R. Adams, Jr., International Paper Co.; W. J. Follette, Crown Zellerbach Corp.

Plant Tours

On Tuesday afternoon many of the conferees took the opportunity to see one of the following plants, which had invited coating conference delegates to visit them:

Corn Products Co., Argo, Ill.
Rand McNally Co., Skokie, Ill.
W. F. Hall Printing Co., Chicago, Ill.
The Chicago Tribune

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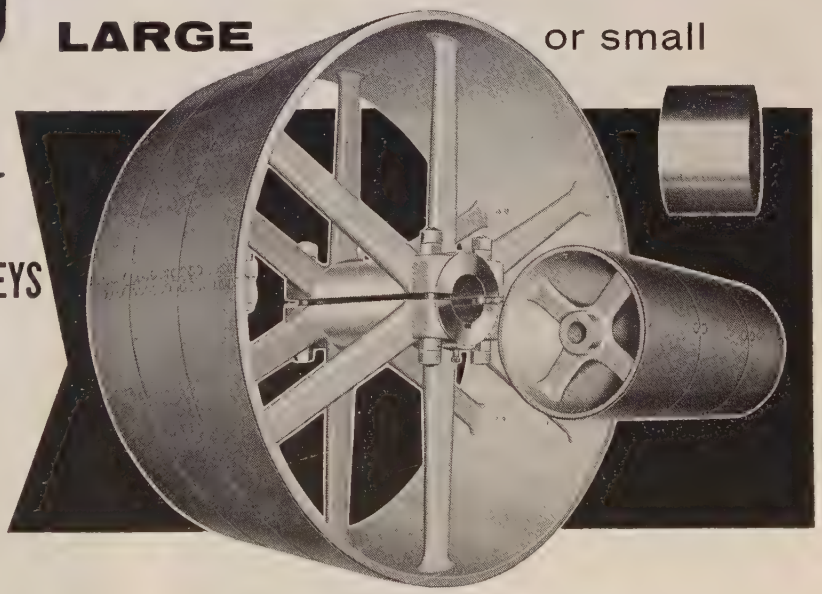

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Fifth Session: J. T. Goodwin, Jr., Corn Industries Research Foundation, Inc.; H. H. Murray, Georgia Kaolin Co.; F. F. Oehme, Consolidated Water Power & Paper Co.; D. C. Nepper, Consolidated Water Power & Paper Co.; W. C. Black, Penick & Ford Ltd., Inc.

In addition, following the conference on Thursday, May 26, a group of delegates visited Beloit Iron Works in Beloit, Wis.

Fourth Session

C. A. Richardson, Blandin Paper Co., Grand Rapids, Minn., was chairman of the fourth technical session, held on Wednesday morning, May 25. Abstracts of the five papers presented are given below.

"Electrostatic Coating Process for Making Flat Gummed Papers," by F. W. Holt, Brown Bridge Mills, Inc., Troy, Ohio; C. Lorenz, Black-Clawson Co., Dilts Div., Fulton, N. Y.; and R. B. Reif, Battelle Memorial Inst., Columbus, Ohio. The Brown-Bridge Mills, Inc., at Troy, Ohio, is now using a new electrostatic dry coating process to eliminate solvents in making flat gummed paper. Water-soluble adhesives and flexible binder material are applied from a dry powder. The laboratory and plant equipment developed in cooperation with Battelle Memorial Institute and Dilts Div. of The Black-Clawson Co. represent the most advanced designs of the new coating equipment. A 60-in. coater and a complete installation for grinding coating powders are in operation in the plant at Troy, Ohio. Further application of the new process in making other products is predicted.

"Design and Operation of a Pilot Plant Coater," by E. D. Jones Crossett Paper Mills, Crossett, Ark., and N. H. Laughrey, Black-Clawson Co., Dilts Div., Fulton, N. Y. Current interest in coating machinery indicates a trend wherein extreme versatility is desired in order to handle a wide range of coating materials and webs. In order to cope with this problem, and eliminate improper selection of equipment, a great deal of emphasis is being placed on the need and necessity for pilot plant coating equipment to evaluate the proper methods of handling this wide range of coating materials and webs.

Discussed in the paper are the reasons for research and development in coating and its importance in relation to the proper selection of equipment for commercial production. From the results of pilot plant coating machinery are gathered the data to insure the proper equipment and the features and versatility required in production machinery.

A section of the article is devoted to the mechanical design of the equipment and the features built into the equipment in order to provide maximum flexibility for research and development work. The importance of the proper layout and arrangement of the various components of the coating machine line are discussed, particularly in view of the problem often faced by the machinery builder of space limitation. The various methods of coating are described including the air doctor, blade coater, gate roller coater, kiss roll applicator, and other methods.

R. W. Hagemeyer, Wyandotte Chemicals Corp.

"A Method to Determine the Degree of Wet Rub Resistance," by F. R. Adams, Jr., International Paper Co., New York, N. Y. Wet rub resistance is a paper characteristic which has been of interest to the industry for many years, but which has been limited in its significance by the highly subjective methods used in its determination. This paper covers the conception and development of a wet rub test which is entirely objective in nature, highly reproducible, and not limited by the paper coating base. By determining the degree of wet rub resistance it is possible not only to separate the blacks from the whites, but also to arrange the grays in sequential order. The simplicity of this test lends itself to routine control functions as well as the developmental uses indicated by its precision.

"Operating Variables of a Blade Coater," by W. J. Follette and R. W. Fowells, Crown Zellerbach Corp., Camas, Wash. The amount of coating applied by a trailing blade coater is generally considered to be related to the base sheet, the coating color and the doctoring action of the blade.

In carrying out a study of the doctoring action it was found that coating weight varied as a function of doctor blade pressure. A simple method for calculating blade pressure is described. For a system with fixed base stock, coating color, and operating speed, a quantitative statement for the coating weight – blade pressure relationship has been developed. The qualitative effects of variations in base stock, color, and speed are discussed.

"The Champflex Coater," by C. G. Whelpton, Champion Paper & Fibre Co., Hamilton, Ohio. One of the more recent developments in the field of coating paper and board is the Champflex coater. While it is in the general category of trailing blade coaters, the characteristic feature of the Champflex is its use of a small rotating rod held in spring mounting. Rotating against the direction of sheet travel, the rod has the ability to doctor coatings without a tendency for foreign particles to lodge behind the blade causing streaks.

As a consequence, the coater is relatively easy to operate, fairly inexpensive to build, and permits simple coating preparation and handling techniques.

A single coating application can apply a weight of from 3 to 15 lb. per ream (25′ × 38 — 500) per side at solids ranging up to 65%.

H. M. Annis, Oxford Paper Co.

Bert Cremers, Wyandotte Chemicals Corp.

Head Table—Annual Coating Luncheon

Most coaters in common use today have certain characteristics and limitations which prevent them from producing coated products suitable for a great variety of end uses. Accordingly, efforts have been directed toward design of coaters which are adaptable to a wide range of applications.

The versatility of the Champflex coater is emphasized by its successful use both on and off machine, not only to apply pigmented coatings, but also to apply nonpigmented materials which could not be done successfully by other means.

Annual Luenchon

The annual coating luncheon was held on Wednesday, May 25, with R. W. Hagemeyer, general conference chairman, acting as toastmaster. Mr. Hagemeyer introduced the head table guests and members of the conference committee, and spoke briefly of the very large amount of time and effort that goes into the staging of the coating conferences. H. M. Annis, Oxford Paper Co., New York, N. Y., extended the greetings of National TAPPI to the delegates on behalf of TAPPI president J. R. Lientz. Mr. Annis is vice-president of the Association. J. E. Wilber, Coating Committee chairman, introduced the guest speaker, Bert Cremers, vice-president of Wyandotte Chemicals Corp., Wyandotte, Mich. Mr. Cremers addressed the group on the subject "Changes in Marketing Patterns — Opportunities for Technical Men." The text of Mr. Cremers' talk appeared in the August, 1960, issue of *Tappi*.

Coating Committee Meeting, Edgewater Beach Hotel, Chicago, Ill., May 23, 1960

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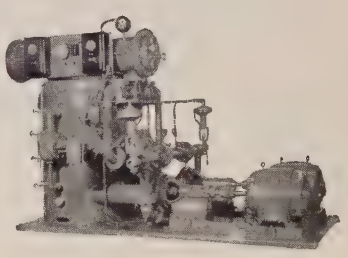

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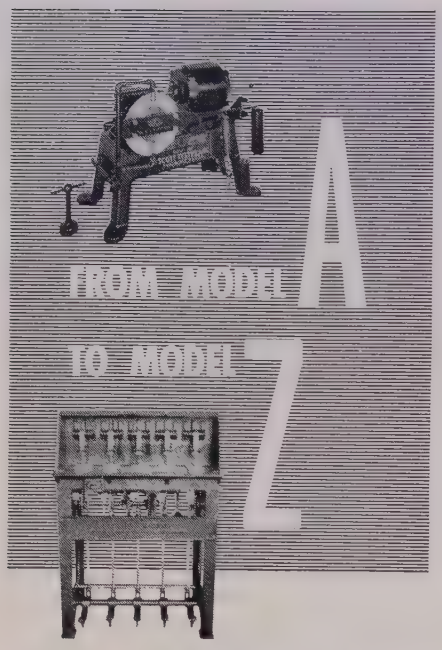

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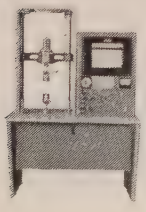

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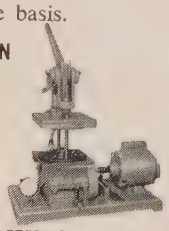

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Fifth Session

J. T. Goodwin, Jr., Corn Industries Research Foundation, Inc., Washington, D. C., was chairman of the final technical session on Wednesday afternoon, May 25, during which three papers were presented. Abstracts of the papers follow.

"A New Precision Technique for Measurement of Coating Thickness," by H. H. Murrary, Georgia Kaolin Co., Elizabeth, N. J. A method for determining precisely the thickness of inorganic coating layers has been developed using an x-ray absorption technique x-ray absorption follows the same laws governing the passage of any form of light through a transparent medium. The mass absorption coefficient was calculated for kaolins and by substitution in proper formulas, the film thickness was determined. Coated sheets of variable weight, utilizing different adhesives and coat weights, were used. The method is rapid and precise and coating thicknesses can be determined with an accuracy of $+ 0.5\ \mu$. The method can be used to determine the thickness of any inorganic coating material and it is believed that the method can be adapted for production control.

"A Laboratory Instrument for Measuring the Piling Propensity of Paper Used in Offset Lithography," by F. F. Oehme and D. C. Nepper, Consolidated Water Power & Paper Co., Wisconsin Rapids, Wis. A definition for piling is given as it pertains to coated lithographic grades of paper with a distinction being made between piling, tinting, wet pick, and wet rub. The conditions which are necessary to produce piling in multicolor offset printing are discussed in relation to the problem of reproducing these conditions in the laboratory for establishing a control test for measuring this property. A detailed description of the development, construction, and operation of an instrument that measures the relative potential of an offset sheet to induce piling is presented as a measure of that sheet's resistance to wet pick.

"Pressure Cooking for Coating Color Preparation," by W. C. Black and V. L. Winfrey, Penick & Ford, Ltd., Inc., Cedar Rapid, Iowa. The degree of dispersion of the granules of a cooked starch paste is a function of the time, temperature, and shear to which the pastes have been subjected. While cooking temperatures above the boiling point of water have been used for starches for laboratory work and certain commercial applications, the improved starch dispersions made possible by the use of elevated cooking temperatures have not been extensively considered for use as paper sizes, coatings, and adhesives.

This paper describes equipment which is now available for continuously cooking starches at elevated temperatures and pressures, and describes the changed properties of the pastes prepared with it. The possible utility of such high-temperature-cooked pastes for paper coating adhesives and paper surface sizes is discussed.

Erratum

T 220 m-60—Physical Testing of Pulp Sheets—as published in the November, 1960, issue of *Tappi*, change the description under the caption of the figure to read; "The depth of the specimens for the tearing test should be 63 mm. and the distance from the base to the point of the slit 20 mm."

Twelfth

Coating Conference

of the

Technical Association

of the

Pulp and Paper Industry

Statler-Hilton Hotel, Buffalo, N. Y.

May 8–10, 1961

TAPPI NOTES

Local Section Activities

During recent years the association has been carrying out a concentrated program to increase aid to the various local sections and districts. The emphasis has been on opening new channels of communication and supplying as much help to the local units as they felt they needed. This aid has taken a number of forms including the establishment of a Local Section Operations Committee, the publication of the Local Section Operations Manual, the creation of a special headquarters staff position for local section matters, an increase in the number of staff contacts with the local sections, and a monthly newsletter.

The Local Section Operations Committee was established four years ago and consists of the chairmen of the 16 local sections as voting members. The Executive Secretary of the Association acts as committee chairman, and other local section and district officers are invited to attend meetings and participate in discussions. The committee meets twice a year, in the fall and at the Annual Meeting in February, providing an opportunity for local officers to discuss their mutual problems and experiences.

"The Manual for the Guidance of Local Sections of the Technical Association of the Pulp and Paper Industry" was published in *Tappi* July, 1957. This manual is the "Bible" of section and district operation and has been made available to all officers for discussion and reference. The manual has recently undergone a revision and will shortly be available in a new edition. Areas covered in the manual include discussion of Association policies, objectives, and organization; local organization and administration; and the duties and responsibilities of local section officers and committees.

Last February, the TAPPI Executive Committee created the new staff position of "Local Section Assistant," for the purpose of providing full-time assistance to local sections and districts. It has been my pleasure to serve in this capacity for the months past and to try to develop a clearer appreciation of the objectives and programs of the Association and its local units. As requests for services and advice have come to headquarters, they have been fulfilled as Promptly and completely as possible. As many of our readers know, our local sections have great autonomy in conducting their affairs, and it has not been the wish of the Association to impose its methods and ideas upon its sections, but rather to advise and counsel them when specifically asked to do this.

By opening up new channels of communication, including the establishment of the monthly "Local Section Notes," sent to all local officers from National TAPPI, it has been possible for the officers of various sections to exchange ideas among themselves and with the Association headquarters office.

The interests of the local units are best served when each can develop its own program, traditions, and methods of operation. It is interesting to note that most local sections have a particular specialty on which they concentrate. For instance, the Lake Erie, Chicago, and St. Louis Sections are primarily interested in converting operations, whereas the New England Section interests itself in specialty paper manufacture, and the Southeastern Section in kraft pulping and papermaking.

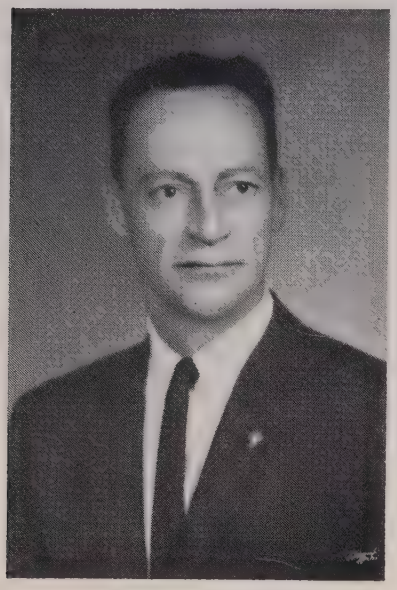
Local sections are located in the principal pulping, papermaking, and converting areas of the United States, and there is also one in northern Italy. At present there are 16 local sections and nine districts of local sections. Approximately 5000 persons have been active in sections and districts during the past year; 2700 of these are members of TAPPI, and the balance are affiliated only with the local units.

People affiliate with local sections for a variety of reasons, but local sections fullfill a need in three distinct areas. They are the areas of education, professional development, and a fellowship among people with mutual interests. In the field of education the local unit provides an opportunity for papers to be heard on subjects of interest to the group, and for operating problems to be viewed directly on the operating scene through the media of mill tours. On the professional side, men are given the opportunity for professional development by presenting papers, by serving as officers and committee men for local section or district, and by informal discussion at meetings of mutual problems with their fellows. Finally, a local section fulfills, in a highly professional way, an important side of a TAPPI member's social life. Here at the local meeting a member is confronted with the industry as a group. Many important and lifelong friendships have been developed at local section meetings, and if we may borrow a phrase from a certain national magazine, a healthy sense of "togetherness" is developed.

To summarize, the Association's desire to aid the sections without restricting their freedom of action, has increased substantially during recent years and will continue to increase. The local units provide an important base to the association which, taken with the activities of the technical divisions and committees, go to make up our organization. The local sections provide an important bridge between the member and nonmember and are an excellent means of bringing many people into our Association. The sections meanwhile contribute importantly to an individual's technical education, professional and social development.

J. W. Field
Local Sections Assistant

TAPPI PROFILE



Kenneth D. Running

KENNETH D. RUNNING, a member of the TAPPI Executive Committee, is a director of the Halifax Paper Co., Roanoke Rapids, N. C., and superintendent of its sulfate department.

Born in Saskatoon, Saskatchewan, where his father was manager of the Kaufman Rubber Co. of Saskatoon, he received his primary education there, and won the Hugh Cairns, V.C., award for scholarship and leadership. At the University of Saskatchewan he took the honors course in chemistry and graduated B.Sc. in 1934. He stayed on to do graduate work and one year later received an M.Sc. degree. While a student he served as a laboratory instructor in organic and biochemistry.

Immediately upon graduation he came east and joined Anglo-Canadian Pulp and Paper Mills in Quebec City, Quebec, where he worked in the research department and in control. In 1940 he was made assistant superintendent of a sister company, Gapesia Sulphite in Chandler, Quebec. During the war he was assigned to Allied War Supplies Corp. as an administrator of the Canadian Government Chemical Plants. In 1945, immediately after the war, he went to Port Royal Pulp and Paper in Saint John, New Brunswick, as superintendent. Three years later he joined the Halifax Paper Co. (a wholly owned subsidiary of Albermarle Paper Manufacturing Co., Richmond, Va.) as superintendent of the sulfate department. In 1957 he was appointed a director of the company: it was at Halifax Paper, then the Roanoke Rapids Paper Manufacturing Co., that the first sulfate mill in the United States went into operation, in 1909.

Kenneth Running has been a member of TAPPI since 1946. As a member of the Alkaline Pulping Committee since 1949, he has served as secretary, assistant chairman, and program chairman; he was last program chairman in 1959, at the 13th Alkaline Pulping Conference in Jacksonville, Fla. He was active in the formation of the Virginia-Carolina Local Section of TAPPI, and has served as an executive committee member of the Section since its inception. As an expert on kraft pulping operations he is currently on the Editorial Board of *Tappi*.

Formerly a member of the Canadian Pulp and Paper Association, he is a past chairman of the Newsprint Section Committee. While on the committee he published many papers on the utilization of hardwoods, a subject in which he is especially interested. It was on this subject that in 1941 he received the C. Howard Smith Award for the best paper contributed by a junior member.

In broader spheres of activity Kenneth Running serves many civic organizations. He is a director of the Roanoke Rapids Chamber of Commerce; a director and vice-president of the Rosemary Federal Savings and Loan Association; and a director of the local Kiwanis Club. Having served as a fund chairman and director, he is presently vice-president of the Coastal Plain Heart Association and also a director of the North Carolina Heart Association. Since being recognized in 1948, the American Heart Association and its affiliates have contributed almost $50 million to scientific research. During the last decade, the Heart Association has emerged as the Nation's largest nongovernmental source of support for scientists engaged in research related to the heart and circulatory system.

The father of two sons, Kenneth (18) and Robert (15), both he and his wife, the former Estelle Walker of Saskatoon, take an active part in all school activities. Keenly interested in better schools, Kenneth Running has acted as chairman of various Parents and Teachers Association Committees. He organized the local cub scout organization in Roanoke Rapids and served as committee chairman for several years. He is a member of the First Presbyterian Church.

For relaxation Mr. Running can turn to many interests. He is a member of the Chockoyotte Country Club, and enjoys golfing, swimming, and gardening. He is fond of good music, is an avid reader, and an amateur astronomer.

PERSONAL MENTION

New TAPPI Members

Charles L. Amateis, Sales Representative to Paper Industry, Keever Starch Co., Columbus, Ohio.

Bernard Ancelle, Chief of Laboratory, Societe Progil, Dordogne, France.

W. Lewis Ayers, Sales Engineer, Rice Barton Corp., Worcester, Mass., a 1948 graduate of Wentworth College.

Russell F. Barnes, Librarian, James Jerome Hill Reference Library, St. Paul, Minn., a 1935 graduate of Miami University (Ohio).

Robert M. Benjamin, Regional Group Leader, St. Regis Paper Co., Deferiet, N. Y., a 1950 graduate of Nova Scotia Technical College.

M. Blanc, Engineer, Progil, Paris, France.

Philip L. Carter, Jr., Regional Representative, Weyerhaeuser Co., Chicago, Ill., a 1952 graduate of Tufts University.

Nallan C. S. Chari, Staff Chemical Engineer, Owens-Illinois, Toledo, Ohio, a 1954 graduate of Banaras University, India, with a Sc.D. degree in 1960 from University of Michigan.

Morris Cordova, Paper Project Chemist, St. Regis Paper Co., Pensacola, Fla., a 1952 graduate of University of Miami (Fla.).

John W. Croft, Technical Sales Representative, E. I. du Pont de Nemours & Co., Houston, Tex., a 1943 graduate of Clemson College.

L. Marie Diedrichs, Librarian, Ferro Corp., Cleveland, Ohio.

Willard G. Engelgau, Maintenance Engineer, Central Engineering Div., St. Regis Paper Co., Jacksonville, Fla., a 1950 graduate of Michigan State University.

Jan H. Fasmer, Technical Manager, Alvoens Papirfabrik A/S, Alvoen, Norway, a 1928 graduate of Kothen-Anhalt, Germany.

David A. S. Holmes, Manager, Special Projects, All-Packs (Aust.) Pty., Ltd., N.S.W. Australia, a 1941 graduate of Brisbane Technical College.

Jerome B. Hudon, Manager, Packaging Materials Laboratory, Kellogg Co., Battle Creek, Mich.

Paul W. Jacobsen, Manager, Research and Development, H. G. Weber & Co., Inc., Kiel, Wis. Attended Rutgers University.

Ora W. Johnson, Jr., Supervisor, Quality Control, St. Regis Paper Co., Pensacola, Fla., a 1950 graduate of Milligan College.

Otto J. Kallmes, Senior Research Chemist, St. Regis Paper Co., Carthage, N. Y., a 1959 graduate of the Institute of Paper Chemistry with a Ph.D. degree.

Koichiro Kitao, Professor, Wood Research Institute of Kyoto University, Kyoto, Japan, a 1934 graduate of Kyoto University.

Chester F. Koda, Chief, Microbiological Laboratory, Nuodex Products Co., Elizabeth, N. J., a 1953 graduate of Syracuse University with a Ph.D. degree.

Clermont H. Lorenz, Manager, Sales Service, Black-Clawson Co., Dilts Div., Fulton, N. Y., a graduate of College of the City of New York.

Earl W. Malcolm, Graduate Student, the Institute of Paper Chemistry, Appleton, Wis., a 1959 graduate of Western Michigan University.

Charles J. Miller, Assistant Group Leader, St. Regis Paper Co., Carthage, N. Y. Attended Drexel Institute of Technology.

Frank R. Monaghan, District Representative, Nalco Chemical Co., Inc., Chicago, Ill., a 1948 graduate of St. John's University.

Ashley D. Nevers, Project Leader, Pennsalt Chemicals Corp., Wyandotte, Mich., a 1942 graduate of University of New Hampshire.

Charles D. Norlander, Jr., Chief, Paper Laboratory, Ecusta Paper Div., Olin Mathieson Chemical Corp., Posgah Forest, N. C., a 1936 graduate of North Carolina State College.

Navnitlal B. Patel, Technical Adviser and Director, Cellulose Products of India, Ltd., Agmedabad, India, a 1953 graduate of University of Bombay.

John D. Pawling, Manager, Manufacturing & Engineering Services, Hinde & Dauch, Ltd., Toronto, Ont., Canada, a 1948 graduate of University of Toronto.

Paul F. Pratte, Technical Supervisor, Container Laboratory, St. Regis Paper Co., Pittsburgh, Pa., a 1955 graduate of Northeastern University.

Ivan Regan, Chemist, Messrs. Globe Products (Accrington), Ltd., Lancashire, England, a 1954 graduate of College of Technology.

Thomas J. Schoch, Research Group Leader, Corn Products Co., Argo, Ill., a 1928 graduate of Columbia College with a Ph.D. degree in 1933.

Jean R. Scohy, District Engineer, Westinghouse Electric Corp., St., Louis, Mo., a 1941 graduate of University of Oklahoma.

Milton F. Spain, Student, North Carolina State College, Raleigh, N. C.

Raylene M. Steelman, Librarian, Arkansas A & M College, College Heights, Ark.

Chesley M. Tredway, III, Development Engineer, Albemarle Paper Mfg. Co., Richmond, Va., a 1957 graduate of Virginia Polytechnic Institute.

Appointments

Antonio Anfossi, formerly of Beloit Italia, is now General Manager of Burgo Bowater Scott, Turin, Italy.

Richard C. Breiner, formerly of Johns-Manville Corp., is now Project Director for Nicolet Industires, Inc., Florham Park, N. J.

Philip A. Cerasoli is now Assistant General Superintendent of the Hamilton Paper Co., Miquon, Pa.

L. Baxter Chamberlain, formerly of Europa Carton A/G Hoya, Weser, Germany, is now with the Container Corp. of America, Chicago, Ill.

Peter J. Child, formerly of Alex Pirie & Sons, Ltd., is now Manager of the Vegetable Parchment Mills (Delcroix), Ltd., St. Marys Cray, Orpington, England.

Julio Colon, formerly of La Aurora S/A, is now Controller of Kimberly-Clark de Mexico S/A, Nancalpan de Juarez, Mexico.

Solis Dudnick, formerly of National Manufacturing Co., is now Chief Engineer of Sweetheart Paper Products Co., Inc., Chicago, Ill.

Richard L. Elderkin, formerly of Consolidated Paper Corp., Ltd., is now with Scott Paper Co., Chester, Pa.

Thomas R. Elmblad of the Swenson Evaporator Co. has been transferred from Cleveland, Ohio, to New York, N. Y., as District Manager.

James W. Field, formerly of TAPPI, is now Field Director of the Packaging Institute, New York, N. Y.

John N. Franklin, formerly of the Tasman Pulp & Paper Co., is now the Canadian representative of Bowen Corp., Montreal, P. Q.

Roswell P. Fallon of St. Regis Paper Co. has been transferred from Herrings, N. Y., to the Cornell Paperboard Products Division, Milwaukee, Wis., as Production Manager.

Karl F. Halladin, formerly of the Waldorf Paper Products Co., is now General Superintendent of Mac Sim Bar Paper Co., Otsego, Mich.

K. M. Paul Hsi, formerly of Ebasco Services, Inc., is now a Project Engineer for Stadler, Hurter & Co., Montreal, P. Q., Canada.

Bertil Ivarson, formerly of Munksjo A/B, is now with A/B Papyrus, Molndal, Sweden.

Robert E. March, formerly of the Coos Bay Pulp Division, is now Paper Mill Manager of Scott Paper Co., Everett, Wash.

Jerome C. Marquardt of the Marathon Division of American Can Co. has been transferred from Oswego, N. Y., to Naheola, Ala., as technical Assistant to the Plant Manager of the Marathon Southern Corp.

Raymond P. McGinley, formerly of Missisquoi Corp., is now Service Manager of Penobscot Chemical Fiber Co., Old Town, Me.

James M. Naughton of Olin-Mathieson Chemical Corp. has been transferred from Baltimore, Md., to New Orleans, La.

Robert K. Newcomb, formerly of John Waldron Corp., is now President and General Manager of Rotobond, Inc., Bound Brook, N. J.

Edward Novick of Dow Chemical Co. has been transferred from Midland, Mich., to Boston, Mass.

William R. Palmer of Link-Belt Co. has been transferred from Shreveport, La., to Dallas, Tex.

Harry B. Parker, formerly of KVP Sutherland, is now a Technical Representative for Hodag Chemical Corp., Kalamazoo, Mich.

Fred R. Paul, formerly of American Cyanamid Co., is now a Chemist with Ditto, Inc., Chicago, Ill.

Richard K. Strapp, formerly of Carthage Machine Co., is now Technical Service Manager of Thurso Pulp & Paper Co., Thurso, P. Q., Canada.

James S. Tipka, formerly with Boler Petroleum Co., is now Technical Representative for Waterbury Felt Co., Inc. Division of Porritts & Spencer, Ltd., Skaneateles Falls, N. Y.

Reginald L. Wakeman, formerly with Packaging Corp. of America, is now with Onyx Chemical Co., Jersey City, N. J.

John W. Welch of Huyck Felt Co. has been transferred from Rensselaer, N. Y., to Newburg, Ore., as a chemical engineer.

Virginio Zani, formerly of Sesacolor, is now Managing Director of Black-Clawson Italia, Milano, Italy.

* * *

Jaime Ortiz Mena has been succeeded by *Sergio Caraveo*, Manager, as the official corporate representative of Celulosa de Chihuahua, Chihuahua, Mexico, in TAPPI.

James R. Schoettler, Technical Director, has succeeded *Roy V. Weldon* as official corporate representative of the Great Northern Paper Co., Millinocket, Me., in the Technical Association.

Albert M. Hendricks has succeeded *J. L. Mullin*, retired, as the official corporate representative of the Hopper Paper Co., Taylorville, Ill., in TAPPI.

Birger W. R. von Kraemer, General Manager, has succeeded *H. Haavisto* as the official representative of Wartsila-Koncernen A/B, Helsinki, Finland, in TAPPI.

J. G. L. Cualfield has succeeded *Charles M. Koon* as the official corporate representative of the Eastern Fine Paper & Pulp Division of Standard Packaging Corp., Bangor, Me., in the Technical Association.

K. W. P. Gibbon has succeeded *D. G. Petrie*, retired, as the official corporate representative of Star Paper Mills, Ltd., Feniscowles, England, in TAPPI.

Henri Renard has succeeded *Michel Rouilly* as the corporate representative of Papeteries de France, Paris, France, in the Technical Association.

* * *

Ray E. Harter has succeeded *Charles H. Champion*, deceased, as the official representative of R. T. Vanderbilt Co., New York, N. Y., in TAPPI.

C. E. Buchan has succeeded *E. W. Forschner*, deceased, as the official representative of Electric Machinery Mfg. Co., Minneapolis, Minn., in TAPPI.

Donald L. Rosen has succeeded *T. R. Wilbert* as the official representative of Gottesman & Co., New York, N. Y., in TAPPI.

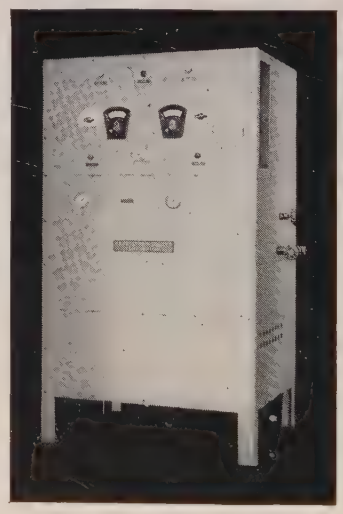
G. T. Abernathy has succeeded *D. G. Moorhead* as the official representative in TAPPI of the Newport News Shipbuilding & Dry Dock Co., Newport News, Va.

William C. Taylor has succeeded *R. B. Martin* as the official representative in TAPPI of Wallace & Tiernan, Inc., Newark, N. J.

David Bossen has succeeded *H. R. Chope* as the official representative in TAPPI of Industrial Nucleonics Corp., Columbus, Ohio.

YM

Heat Transfer Systems



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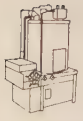

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INDUSTRY NOTES

North American

Statistics

*Paper and Paperboard Production**

Estimated paper and paperboard production for the first nine months of this year totaled 25.8 million tons. Production of paper and board for the comparable period of 1959 was 25.4 million tons. Thus, total production through September, 1960, was 1.6% above the like period of 1959. The following comparisons with the first three quarters of 1959 can be made: paper at 11.5 million tons ran 3.6% ahead of 1959 when the industry produced 11.1 million tons; paperboard production totaled 11.9 million tons as compared to 11.8 million tons in 1959; and construction paper and board production at 2.4 million tons was below the 1959 three-quarter total of 2.5 million tons.

*Pulpwood**

Total receipts of pulpwood for January–August were 27,310,000 cords, an increase of 2,510,000 cords over receipts for the comparable period last year. Domestic receipts were 2,437,000 cords above the year earlier total, and imports increased 73,000 cords. All of the regions showed increases ranging from 3% in South Central to 16% in the North Central region.

Pulpwood consumption for January–August, 1960, was 27,078,000 cords, an increase of 1,332,000 cords over the same period of 1959. All of the regions showed increases ranging from 2% in Northeast and South Central to 10% in the North Central region.

Inventories of pulpwood at the end of August were 5,416,000 cords, an increase of 23,100 cords above July, 1960, and a 496,000 cords increase above August, 1959. Two of the regions showed decreases: South Central decreased 4% and Northeast decreased 7%. Three regions showed increases ranging from 5% in North Central to 71% in the South Atlantic region.

*Wastepaper and Other Fibrous Materials**

August wastepaper receipts were 781,000 tons; for the first eight months of this year they totaled 5,967,000 tons, a decrease of 222,000 tons below receipts for last year.

Wastepaper consumption for August was 783,000 tons; the January–August total 6,012,000 tons, a decrease of 98,000 tons from consumption for the same period last year.

Inventories at the end of August were 542,000 tons, 2000 tons below July and an increase of 28,000 tons above inventories at the end of August, 1959.

Consumption of total fibrous materials for August was 870,000 tons; the January–August total was 6,679,000 tons, 133,000 tons below consumption for the comparable period last year.

Inventories of total fibrous materials at the end of August were 904,000 tons, 5000 tons below July and 28,000 tons above inventories at the end of August, 1959.

*Wood Pulp**

Production of wood pulp for January–August, 1960, was 16,852,000 tons, an increase of 763,000 tons above the comparable 1959 total.

Wood pulp consumption in the manufacture of paper and board for January–August, 1960, was 17,224,000 tons, an increase of 556,00 tons above consumption for the same period last year.

Imports of wood pulp for January–August, 1960, were 1,583,872 tons, 2% below imports for last year. Imports from Canada for January–August, 1960, were 1,354,215 tons, 2% above the comparable period of 1959. Overseas imports for January–August, 1960, were 229,151 tons as compared to 293,029 tons for the same period last year.

Exports of wood pulp for January–August, 1960, were 751,054 tons, as against 403,822 tons exported during the same period last year.

Inventories of wood pulp at paper and board mills at the ends of August were 543,262 tons, 21,000 tons above inventories at the end of July and 600 tons above inventories at the end of August, 1959.

Paperboard

Average weekly production of paperboard is running approximately only 400 tons under the record level established on 1959, Warren F. Wescott, Assistant Statistician, National Paperboard Association, told paperboard executives assembled in New York City at the Association's 28th Annual Meeting held in November.

1959 production averaged 307,100 tons per week as compared with 306,700 tons per week in 1960. Production of containerboard, used in making corrugated shipping containers, is 0.2% higher than 1959 and production of boxboard, used in folding and setup boxes, is only 0.5% lower than 1959 figures.

"While this year's demand has been below earlier expectations of the industry, orders booked here have been comparatively close to the record highs of 1959," Mr. Wescott stated.

"This year, while the total economy has not reached the heights anticipated, and in some industries has lagged considerably behind 1959, our figures show that one of the bright spots is the performance of the paperboard industry. The year 1960 to date, at least tonnagewise, has not been too bad and this industry appears to be heading for a year almost equal to our record productive year 1959," Mr. Wescott concluded.

Arkansas

Arkansas forests have more softwood timber but less hardwood than they did a decade ago, according to a new survey of the state's timber resources. A report of the survey was released today by State Forester Fred H. Lang and Philip A. Briegleb, director of the Southern Forest Experiment Station of the Forest Service, U. S. Department of Agriculture. The survey is an activity of the Experiment Station, whose headquarters is at New Orleans, La.

In announcing the results of the survey, Mr. Briegleb pointed out that "generous assistance from forest industries and the Arkansas Forestry Commission made it possible to complete the huge timber inventory ahead of the schedule that could have been maintained with regularly allotted Federal funds." The industrial cooperators include The Crossett Co.; International Paper Co.; Dierks Forests, Inc.; Bradley-Southern Div. of Potlatch Forests, Inc.; Fordyce Lumber Co.; Ozan Lumber Co.; Deltic Farm and Timber Co.; and Pomeroy and McGowin.

Arkansas' timber supply in sound, well-formed trees at

* American Paper and Pulp Assoc., *Monthly Statistical Summary* 38, No. 11 (November, 1960).

least 5 in. diam amounts to 12 billion cu. ft. Softwood volume has increased 31% since the previous forest survey, which was completed in 1951. Softwoods include the southern yellow pines as well as cypress and red cedar. Hardwood volume has declined 9%.

The volume in trees large enough to make lumber is 41 billion bd. ft. In these sizes, softwood volume has increased 41% while hardwood has dropped 19%.

Improved fire protection, conservative timber harvesting, and removal of low-value hardwoods on areas better suited to pine helped to bring about the increase in softwood. Much of this forestry effort was on public lands and on those held by wood-using industries. Heavy cutting and localized land clearing contributed to the decline of hardwood timber in the bottom lands.

Arkansas' forests are growing 1.6 billion bd. ft. of softwood timber annually and nearly 0.8 billion of hardwood. In 1958, when the latest cutting statistics were compiled, logging removed 0.7 billion bd. ft. of softwood and 0.6 billion of hardwood. In the larger sizes—trees at least 16 in. diam.—hardwood sawtimber is still being cut faster than it is being grown.

The survey also shows that forests cover 20.8 million acres of the state's total land area of 33.6 million acres. This is 7% more forest land than there was in 1951. The increase is largely due to reversion of farmlands to forest.

All together, Arkansas' extensive forest resource supports almost 1000 sawmills, four pulp mills, and some 130 miscellaneous wood-using plants.

A full report of the survey may be secured from the State Forester's office at Little Rock, or from the Southern Forest Experiment Station, 2026 St. Charles Ave., New Orleans 13, La.

Maine

A survey of the timber resources of Maine has been completed by the U. S. Forest Service. This survey was part of the nationwide survey being made by the Forest Service.

Results of the survey are reported in a 75-page illustrated booklet, "The Timber Resources of Maine," which has been published by the Forest Service's Northeastern Forest Experiment Station.

The Maine Forest Service, other State agencies, and a number of industrial concerns cooperated with the U. S. Forest Service in making the 4-year forest survey.

The survey showed that Maine, the Pine Tree State, after 350 years of forest use, has 87% of its land area covered by forests. No other state has so large a proportion of forest land. In terms of pulpwood, Maine's forests contain 205 million cords in standing trees.

This volume includes some 30 billion board-feet in sawtimber-size trees; white pine accounst for 5 billion board-feet.

Of all the timber species found in Maine, spruce is the most abundant. It accounts for 22% of the total timber volume. Balsam fir is the next most plentiful—about 20% of the total. Hardwoods make up about a third of the total volume.

Although Maine forests are growing more than twice as much wood as is being cut, and could support a considerable expansion of the wood-using industry, a large volume of timber—even more than is cut—is lost every year to insects and diseases. Some is lost in fires. Furthermore, the supply of high-quality timber is decreasing. Quality sawlogs are being cut faster than new ones mature. Only 12% of the white pine sawtimber can be classed in the top grade.

The report also suggests measures to realize the full potential of Maine's forest resource.

Copies of the survey report may be obtained from the Forest Commissioner, Maine Forest Service, Augusta, Me.; or from the Director, Northeastern Forest Experiment Station, 102 Motors Ave., Upper Darby, Pa.

Wisconsin

Opportunities for wood-using industries in Northwestern Wisconsin are described in a new report which says that forest growth is far exceeding the timber harvest.

The annual sawtimber cut of approximately 53 million board feet in the 10-county area leaves a surplus of nearly nine million feet that should be cut. The harvest of pulpwood and other products totals about 391,000 cords, while an additional 220,000 cords goes unharvested.

The report, "Opportunities for Wood Industry in Northwestern Wisconsin," is a joint project of the Wisconsin Department of Resource Development, the Wisconsin Conservation Department, and the United States Forest Service and copies of the study and further information are available from the Wisconsin Department of Resource Development or the Wisconsin Conservation Department, both at Madison.

Folding Paper Box Association

The Folding Paper Box Association of America will conduct its annual meeting March 20, 21, and 22, 1961, at the Drake Hotel, Chicago, Ill. The traditional public showing of its annual folding carton competition will be the following day, March 23, in the French room of the Drake.

Fibre Box Association Technical Committee

A. W. Hoffman, quality control manager, Fibre Drum and Corrugated Box Div. of Continental Can Co., New York City, has been re-elected chairman of the Fibre Box Association's Technical Committee.

National Academy of Sciences

The National Academy of Sciences-National Research Council announced today the appointment of Dr. Roy Powell Whitney, vice-president of The Institute of Paper Chemistry, Appleton, Wis., as chairman of the Academy-Research Council's Committee on Paper-Base Materials.

The committee is one of several within an Advisory Board on Quartermaster Research and Development. The Advisory Board is responsible for supplying scientific and technical advice to the Quartermaster Research and Engineering Command, Natick, Mass., on the Command's research and development programs.

Among the applications of paper being considered for further development are: disposable articles of clothing for chemical biological warfare protection; for thermal and radiation protection in nuclear warfare; and to reduce laundry and supply problems in arctic, desert, and jungle operations. Further possible military uses of paper are expendable surgical gowns, gasoline and water containers, cargo parachutes, blankets, sleeping bag inserts, and tentage.

The National Academy of Sciences-National Research Council is a private organization of distinguished scientists devoted to the furtherance of science for the general welfare and obligated, under the terms of its Congressional charter of 1863, to advise the Federal government, upon request, on any matter of scientific or technical interest.

National Bureau of Standards

Two new Technical Advisory Committees have been established by the National Bureau of Standards, U. S. Department of Commerce, one on Calibration and Measurement Services, and one on Engineering and Related Standards.

The committees include leaders in specialized fields, drawn from industry. The purpose of the committees is to aid the Bureau in cooperating with industry in the fields of precision measurement, calibration, and standard practices.

William Wildhack, special assistant to the NBS Director, is chairman of both committees.

1961 Temperature Symposium

The technical program is now complete for the most com-

prehensive meeting ever held on the subject of temperature meausrement. About 200 papers will cover temperature measurements from absolute zero to 10,000,000°K. with interests ranging from the temperature of the human body to the temperature of the sun. Almost every area of the physical, biological, and medical sciences will be represented at the 1961 Symposium on "Temperature, Its Measurement and Control in Science and Industry," to be held in Columbus, Ohio, March 27–31, 1961. The conference is sponsored by the American Institute of Physics, the Instrument Society of America, and the National Bureau of Standards.

University of Illinois

Quality Control Short Course

The fourteenth annual basic short course in Quality Control by Statistical Methods will be presented by the Division of University Extension of the University of Illinois in Urbana from Jan. 30 through Feb. 9, 1961. Intensive work will be given in the fields of control charts, acceptance sampling, and related topics. The course is designed for those in the areas of design, production, procurement, management, quality control, and inspection. For further information, write to: Professor John A. Henry, Mechanical Engineering Laboratory, University of Illinois, Urbana, Ill.

Overseas

Pulp and Paper Exports and Imports—1959

Pulp and paper exports in 1959 were valued at approximately $337 million, which ranked the industry 15th in total value of exports. Pulp and paper imports were valued at $1,089.4 million, placing the industry fourth in value of imports. Total import-export trade of the industry last year amounted to $1,426.4 million, placing the industry seventh in value of total U. S. foreign trade. This year with the surge in pulp exports and the increase in paper and board exports, it is likely that value of U. S. pulp and paper exports may reach $500 million.

It is interesting to note that in direct investments in *manufacturing* enterprises abroad in 1959, the Paper and Allied Products Industry ranked seventh with $811 million. With increasing interest abroad, it is possible that by the end of 1960, the industry may rank fifth superceding Food Products and Electrical Machinery, both of which were only nominally ahead of the paper industry at the end of last year.

—American Paper and Pulp Assoc.

Overseas Pulp and Paper Markets

The U. S. Foreign Service has reported the following countries as marketing possibilities for pulp and paper items; in some cases increasing the already established markets. *Australia:* Corrugating medium, container board liners, glassine and greaseproof paper, special food board, glazed invitation parchment, white patent coated news backboard, party and boxed stationery, wallpapers. *Belgium:* Wood pulp, thin fine paper, special industrial paper, gummed paper and tape, container board. *Colombia:* Wood pulp, printing and writing papers, coarse paper. *Denmark:* Paper and paperboard. *El Salvador:* Paper and paper products. *Germany, Fed. Rep. of:* Bleached and semibleached sulfate pulp, kraft paper and paper board, surfaced and impregnated paper and paper board, novelty household items (such as garbage bags). *Indonesia:* Newsprint and other papers, wood pulp. *Israel:* Container board, cigarette paper. *Mexico:* Wood pulp, newsprint, fine bond paper, wet-strength paper. *Netherlands:* Wood pulp, sulfite or sulfate. *New Zealand:* Special industrial paper, printing and writing paper, vegetable parchment, greaseproof paper, cigarette paper. *Paraguay:* Newsprint. *Peru:* Newsprint, wood pulp. *South Africa, Union of:* Cardboard and fabric-backed board; printing paper, other than newsprint; kraft, stationery, tissues, container board (liners). *Switzerland:* Wood pulp, special industrial paper, gummed paper and tape, coated book paper, facial tissues. *United Arab Republic—Egypt:* Wood pulp for rayon industry. *United Arab Republic—Syria:* Stationery and office supplies. *United Kingdom:* Container board (liners), wood pulp, special industrial paper, kraft wrapping and bag paper, absorbent paper. *Uruguay:* Wood pulp. *Venezuela:* Folding or setup paper boxes, paper sanitary food containers, packaging papers.

—Foreign Commerce Weekly, Nov. 14, 1960.

FAO Pulp and Paper Advisory Committee

A new world advisory body met for the first time in Tokyo recently. A group of the world's leading pulp and paper experts was brought together by director general B. R. Sen of FAO (Food and Agriculture Organization) for this meeting. The group, which will be known as the FAO Pulp and Paper Advisory Committee, has been set up by request of FAO's governing conference to advise Mr. Sen in developing FAO's program in pulp and paper. This has assumed greater importance in the light of the enormous demands which will be made on the industry, especially in the developing countries, in the coming years.

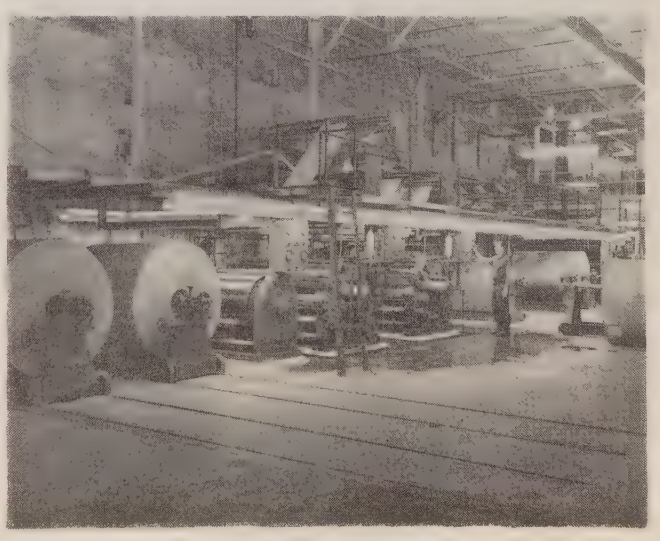
A conference arranged by various U. N. specialized agencies, just concluded in Tokyo, has confirmed that demands for paper and paper products in Asia alone will increase by about three times in the next 15 years. The problems inherent in meeting this enormous demand, brought about by the need to combat illiteracy, meet industrialization needs and raise living standards, will call for considerable help from the established paper-producing countries, if they are to be solved.

Unanimously elected chairman of the new group is R. M. Fowler, president of the Canadian Newsprint Association. Its members include Motoki Matsunaga of Japan, Jean-Pierre Levy of France, Robert O'Connor of the United States, Henry of Australia, V. Podder of India, Carlos Quintana of Mexico, J. O. Soderjheln of Finland, Lars Syonnesson of Sweden, Sir Herbert Hutchinson of the U. K., Dr. Horst Niethammer of Germany, Dr. Fernando Leniz of Chile, and Lorenzo Fernandez of Brazil.

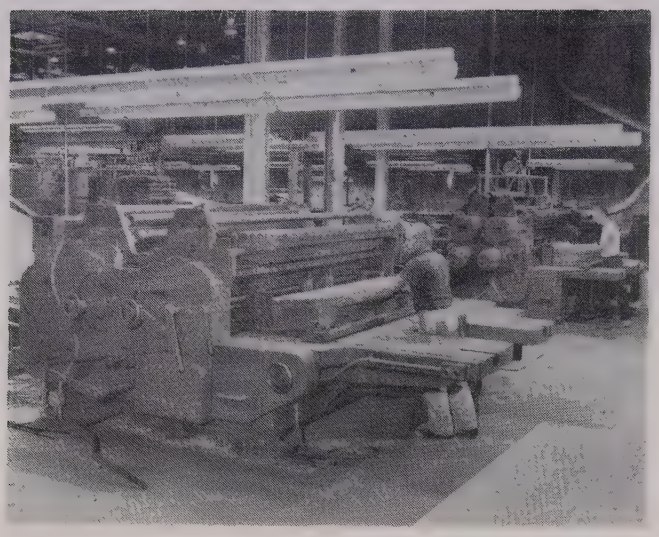
Paper Manufacturers and Converters

Boise Cascade Container Corp.

Production capacity for making corrugated shipping con-



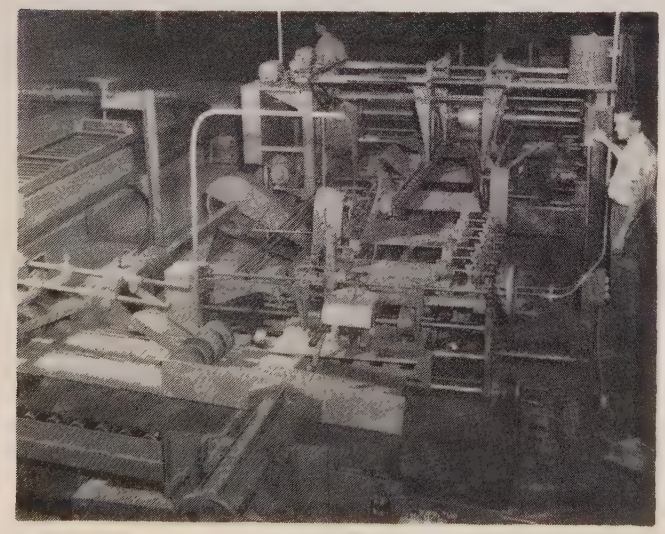
New Hooper-Swift Corrugator at Golden, Colo. plant of Boise Cascade Container Corp. which has just gone into production. This view shows the starting end of 180-ft. machine which is capable of producing nearly 7 miles of 87-in. paperboard in 1 hr. The machine was designed and built by the Metal Products Division of Koppers Co., Inc.



Not exactly newspaper presses, but each of the two Hooper-Swift printer-slotters installed in Boise Cascade Container Corp. plant can print designs and identification in two colors on 15,000 corrugated boxes per hour and, at the same time, cut slots which allow folding of the containers

tainers in the Denver area has been more than doubled with the opening of a new plant near here by Boise Cascade Container Corp., a wholly-owned subsidiary of Boise Cascade Corp.

Located just off 44th St. on Indiana Ave. (the Denver-Golden road) the new plant, which covers 90,000 sq. ft., has just gone into operation. It has the initial capacity to make 30,000,000 sq. ft. of corrugated board per month and convert it into boxes which are extensively used for shipping beverages, canned goods, produce, hardware, meats, and hundreds of additional items.



Production end of folder-gluer installed in Boise Cascade Container Corp. plant by Koppers Company, Inc.

The Golden plant is the third of its kind in Boise Cascade Container Corp.'s chain, plants previously having been put into operation at Wallula, Wash., and Burley, Idaho. A fourth plant presently is being equipped at Sunnyvale, Calif.

Brunswick Pulp & Paper Co.

The Boards of Directors of Scott Paper Co., Chester, Pa., and The Mead Corp., Dayton, Ohio, have approved the $35,000,000 expansion program of their coequally owned affiliate, Brunswick Pulp & Paper Co.

Brunswick's production will be increased 500 tons per day, doubling the operation's present capacity. A new pulp drying machine, a part of the expanded facilities, will make it possible for Brunswick to manufacture bleached board for the first time in its history.

Buckeye Cellulose Corp.

Safety Record

Employees of Buckeye Cellulose Corp.'s pulp mill in Memphis, world safety champions in the pulp and paper industry, have extended their record of injury-free performance to 6,000,000 consecutive man-hours. In a letter congratulating the more than 600 employees of the mill on their achievement, plant manager E. A. Stafford wrote: "I am immensely grateful for your continued interest and effort in safety. You have brought both honor and recognition to Buckeye through your conscientious work in this field." Mr. Stafford estimated that in the current period of safe operations, which began almost five years ago, some 55 employees have been saved from disabling injury. This, he explained, is the number of lost-time accidents that would normally have occurred if the plant had been operating at the industry average.

Champion Paper & Fibre Co.

Plans to build a $431,700 industrial waste disposal treatment plant south of Hamilton have been announced by The Champion Paper and Fibre Co. today. This new facility is a part of the company's long-range program for stream improvement as required by the Ohio Water Pollution Control Board. The new plant will be constructed on Champion property across from the city's sewage treatment plant. Work is to begin at once. An initial contract for $387,000 has been awarded to The Charles H. Shook Co., Inc., of Dayton, builders of the municipal sewage plant and the South Water Works treatment plant.

Fraser Paper, Ltd.

No. 7 Paper Machine

Designed primarily for the production of light and medium weight papers from bleached chemical wood pulp, the new 234 in. no. 7 paper machine, recently installed in the bond paper mill of Fraser Paper, Ltd., is now in continuous operation.

This is the first paper machine added by the company since no. 6 was erected in the company's catalog paper mill in 1930. Number 4 machine was replaced by a new machine in 1954 and the others have been modernized in the past few years.

The construction of no. 7 machine was begun by Pusey and Jones Corp. and completed by John Inglis Co., Ltd. its overall length, including the headbox and winder is approximately 300 ft. and its width, with drive units and hood, is about 60 ft.

Designed for a maximum speed of 2000 f.p.m., the new machine is currently producing at a rate exceeding 100 tons per 24 hr.

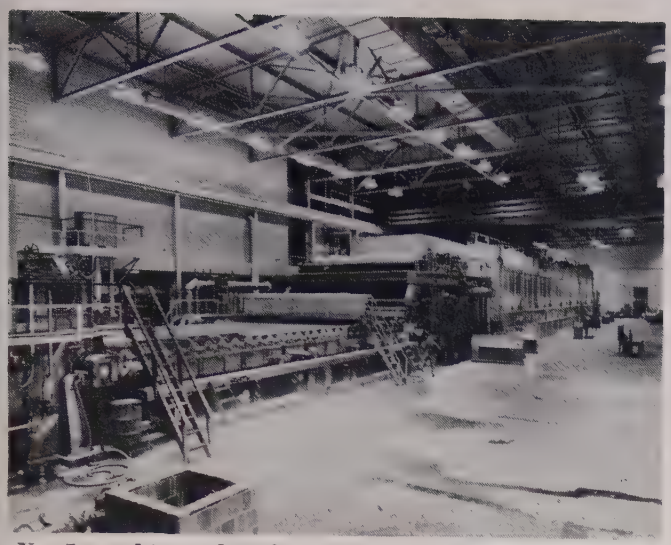
Structural Changes

A new addition of sufficient size to house two paper machines was erected adjacent to the bond mill. It covers an area of 44,000 sq. ft. A second machine will be installed in it when conditions warrant.

The addition has concrete foundations and basement walls, steel frame, brick and glazed tile upper walls and a roof of asbestos cavity deck type covered with insulation and smooth surface built-up roofing.

Stock Preparation

Supplied by Black-Clawson, a system of vertical tile chests having vertical bronze agitators was installed for the



No. 7 machine taken from wet end—Fraser Paper, Ltd., Madawaska, Me.

various pulps used. Blend and machine chests are of same construction.

An 18-ft. Hydropulper will defiber baled pulp for this machine.

Color and additive tanks are of stainless steel as are the agitators.

Blending of the various pulps, colors, and additives is controlled through a system of Foxboro magnetic flowmeters and DeZurik V-port valves with air motor operators. A central control panel enables the operators to vary these proportions and also contains pushbuttons for the pumps and agitators.

Stock consistencies are controlled by DeZurik pipe line type regulators.

Two Emerson no. 303 Claflins and one Black-Clawson no. 5 jordan provide necessary stock treatment. The jordan load is automatically controlled by couch vacuum.

Bauer Cleaners are located ahead of three Bird no. 14 centriscreens.

The fan pump is an Ingersoll-Rand 18ALV. It is rated at 18,000 g.p.m. at 185 ft. head and is driven by a 900-hp. G.E. motor.

Stock pumps were supplied by Goulds and by Black-Clawson and the water pumps supplied by Ingersoll-Rand.

Headbox

The air-loaded enclosed headbox was supplied by Valley Iron Works. It is stainless steel lined.

Fourdrinier

The wire is 234 in. wide by 118 ft.-4 in. long. A single breast roll is used with Micarta tipped forming board and deflectors and 22 rubber-covered table rolls. Space for eight suction boxes is provided although seven will be used at first. Covers are end of grain wax impregnated maple or Robalit. A 30-in. diam. dandy roll and 30-in. diam. lump-breaker roll are each provided with individual drives. Wire return rolls are bronze and the wire guide roll is rubber covered. The 44-in. diam. Black-Clawson suction couch roll has a 6–10 in. adjacent suction box. A couch drive roll is provided although there will not be a suction pickup on the machine at present. The wire pit is a two-pass type with a longitudinal skimming trough incorporated in the midfeather and was supplied by Stebbins Engineering and Mfg. Co. The fourdrinier is equipped with the latest "Rapi-drape" wire handling device.

Press Section

The press section consists of a straight through first press with Beloit suction roll, an inverted second press with Beloit suction roll, and a smoothing press. Both suction rolls have 4 to 8 in. adjustable suction boxes and are 40 in. diam. Pusey and Jones automatic air guides and Bird Vickery felt conditioners are used.

Main Drier Section

The main drier section consists of 30 paper driers and six felt driers all 5 ft. in diameter. The gear train is totally enclosed. Johnson steam joints are used. The driers in this section are designed for 75 p.s.i. except for two paper driers which are designed for 125 p.s.i.

Size Press

The size press is of the horizontal type having rubber covered rolls in both the fixed and movable positions. It is followed by a $11^1/_4$ in. diam. paper roll and Mount Hope expander roll.

After Driers

This section consists of eight paper driers and two felt driers all designed to 125 p.s.i.

Drier felt tighteners in both sections are motor driven, felt guides are pneumatic and both sections are equipped with rope transfers.

Calender Stack

The stack has a 34-in. diam. bottom roll and seven 18-in. diameter intermediate rolls carried on antifriction bearings in a steel frame. The rolls were supplied by Farrell-Birmingham Co. Rolls are raised or lowered electrically with pneumatic loading. A hydraulic nip-relief system was supplied. The doctors are pneumatically loaded and hydraulically oscillated.

Reel

The reel is of the Pope type with horizontal track, pneumatically loaded. An electric drive accelerates the reeling mandrels which are rubber covered. The reel drum is water cooled and the doctor is electrically oscillated. A Mount Hope expander roll precedes the reel.

Miscellaneous

The oiling system for the drier gears and bearings and for the calender bearings is a Bowser system having a capacity of approximately 3000 gal.

All doctors on the machine are Lodding doctors. Those on wet end service are of noncorrosive construction.

Shower pipes for the fourdrinier are Emerson.

A Beloit flat box vacuum control system was also installed.

No. 7 machine from the dry end—Fraser Paper, Ltd., Madawaska, Me.

Hydraulic and pneumatic operators' controls are contained in consoles mounted on the tending side of the machine.

Drier Drainage

A Mason-Neilan system was supplied. The main steam supply is from the mill's 25 p.s.i. system. Higher pressure steam when needed is supplied from the 250 p.s.i. system through a reducing and desuperheating station. Differential controls allow the use of flash steam from various sections to succeeding sections. There are also individual controls on eight bottom driers in the main section and four driers in the after section to provide graduated temperatures.

Drive

The machine is driven by a Reliance sectional generator type drive with transistor magnetic amplifier control. It has a range from 250 to 2000 f.p.m. The generators and controllers are located in a separate room in the basement. Helper motors are supplied on the dancy roll, lumpbreaker roll, press paper rolls, size set drier, and reel mandrel accelerator. Operators controls are located in console-type panels on the tending side of the machine.

Winder

The winder is a Cameron type 480 score cut and is designed for a maximum speed of 5400 f.p.m. It is equipped with a Westinghouse drive and regenerative braking. A hydraulic roll lowering table and core pulling and loading equipment were also supplied by Cameron.

Ventilating System

A totally enclosed hood and ventilating system was furnished by J. O. Ross Engineering. Stainless steel economizers are used. Ross also supplied a calender cooling system and cooling systems for the drive motors and substations. A Grewin system, felt drying system, aisle ventilation, and necessary controls for the ventilation system likewise are by Ross. Fans and economizers are mounted on a mezzanine floor of the machine room rather than in a rooftop penthouse as on other machines in the mill.

Broke Handling

Improved Machinery Co. supplied an agitator for the couch pit, a shredder conveyor pulper at the press section and a two rotor Solvo pulper at the dry end. All are of stainless steel construction. Link-Belt Co. furnished a multiple belt conveyor to handle broke from size press, calender, and reel to the Solvo pulper. A tile broke storage chest is also located at the dry end.

Vacuum System

Nash Engineering supplied the vacuum pumps for the machine as well as for the drier drainage system, Bauer cleaner rejects, and headbox loading. The main machine pumps are of the multiple inlet type and are mounted in tandem in pairs driven by a common motor for each pair.

Saveall

A Dorr-Oliver American disk-type saveall with space for 16 disks will handle water from the couch pit, returning reclaimed stock to the machine chest. Clarified water will be used on showers and for dilution where required.

General

To maintain cleanliness throughout the system, extensive use has been made of tile chests, both stock and water, and tile lining on the couch and wire pits. Stainless steel or bronze agitators are used. Pipe lines and valves are of stainless steel or brass. Some PVC piping has been used on alum lines.

To supply services such as steam, air, water, and electricity to the new building new lines were run from existing sources. In some instances this involved relocating or replacing the present lines.

In anticipation of the added demand for pulp to supply this machine, two additional pipe lines were laid linking the pulp mill in Edmundston, N.B., to the paper mill in Madawaska. A third line was partially installed and will be completed when required.

Also in anticipation of the increased production from this machine as well as to relieve a crowded situation, an addition to the finishing room and a loading shed were built in 1959. This provided more than 42,000 sq. ft. of floor space on the main floor and some 30,000 sq. ft. in the basement. The loading shed will accommodate 30 freight cars and ten trailer trucks. More trucks can be accommodated if necessary.

To service the larger rolls of no. 7 machine, a Farrell-Birmingham roll grinder was installed in a separate addition which also has facilities for spare roll storage for the bond mill.

Georgia-Pacific Paper Co.

Georgia-Pacific Paper Co.'s new Olympia, Wash., corrugated box plant, expected to be completed in March, will utilize basic machinery furnished by the Metal Products Division of Koppers Co., Inc.

The paper company is a wholly-owned subsidiary of Georgia-Pacific Corp., the nation's largest plywood maker and a major lumber producer. The Georgia-Pacific plant will convert kraft liner from the company's newly expanded 600-ton pulp and paper operation at Toledo, Ore.

Gulf States Paper Corp.

Gulf States Paper Corp.'s Demopolis mill chalks up another first with the south's initial successful outdoor chip storage and recovery unit.

Chips began to be piled outside during the firsr part of this year on an experimental basis. The success of this storage method has been proved over the summer months. According to Bob Frese, procurement supervisor, Demopolis, stacks of 1500 units (about 3750 tons) of chips can be stored at one time. He said that 3 months was the longest they have been kept outside, but it is thought they could remain there longer and with less damage than wood in log form.

The Demopolis plant receives chips by truck and by railroad car. From each they are unloaded into a pit. The trucks and trailers are tilted on a hydraulic lift allowing the chips to fall out the rear end into the pit. Dump-bottom hopper cars run on tracks over the pit and a top car shaker speeds the unloading.

Once in the pit, the chips are conveyed to a blower which shoots them onto either of two concrete slabs in the woodyard; or, if needed, directly to the chip silos. The piled up chips are kept outdoors until they are needed.

As they are to be used a tractor with a scoop mounted on the front shovels them back into the pit. This is the recovery part of the system. The conveyor operator sees that hardwood chips are separated from pine chips before the blower picks them up and sends them to one of the three chip silos. From the silos the chips enter the pulping process.

Only in the past few years has Gulf States Paper purchased chips. Previously all wood used by the company came in the form of logs. Since chips are now purchased from sawmills, a bulk storage place was needed. Other southern plants which had been using chips had stored them inside.

Although outside chip storage has been practiced in the West, southern paper mills have been reluctant to use it because of the fear of decomposition and insect damage in the warm and humid South.

About 15% of the Demopolis wood requirement is in the form of wood chips. Frese added that presently a fourth of this 15% is in the form of hardwood chips.

Hudson Pulp & Paper Corp.

Hudson Pulp & Paper Corp. has acquired all of the outstanding stock of Angel Soft Tissue Mills, Inc. in Thomson, N. Y., for an undisclosed sum Hudson President William Mazer has announced. Plans are for continuation of all present Angel Soft operations under Angel Soft management as a separate company.

Knowlton Brothers

Knowlton Brothers, specialty paper manufacturers of Watertown, N. Y., announce the installation on their pilot fourdrinier of equipment to make Clupak extensible paper. Clupak, Inc. has made the equipment available to Knowlton Brothers for the purpose of studying possible applications of Clupak equipment in the specialty papermaking field.

The pilot machine with the Clupak equipment will be available to other paper manufacturers on a lease basis, so that they can explore the use of the Clupak equipment on their papers in pilot production. In this way, the necessary know-how and experience to properly evaluate the application of the equipment can be obtained at modest expense.

Lowe Paper Co.

Recently Lowe Paper Co. has expanded its facilities for producing high gloss clay coatings. The heart of this equipment consists of a calender built by the McKiernan-Terry Corp., of Harrison, N. J. This calender is an open face machine, using chromium plated, internally heated, steel rools with alternating resilient backing rolls. The development of this novel process by Lowe was begun many years ago and has enabled the company to maintain its tradition of leadership in the field of high quality clay coated products.

Mead Corp.

The Mead Corp. has revealed plans for a 40% increase in facilities at the Atlanta plant of the Mead Packaging Division. Contracts for the multimillion dollar building project are expected to be awarded in December and construction will begin immediately thereafter, it was announced by Arthur L. Harris, vice-president of The Mead Corp. and general manager of the Mead Packaging Division.

The 218,000 sq. ft. addition will adjoin Mead Packaging's two production plants at 950 West Marietta St., N.W., occupying the former 14-acre Bellwood Railroad yards recently purchased by Mead from the Atlantic Coast Line Railroad Co. Of modern design, the new building will be of masonry construction with structural steel framing and glass block windows. The 175,000 sq. ft. main area will be utilized for manufacturing and warehousing. Additional facilities will include a 21,000 sq. ft. roll-stock storage building plus coating and color areas totaling 23,220 sq. ft. The latest automatic conveyor and roll-stock handling systems will facilitate storage and movement.

More than 1300 persons are employed on Mead Packaging's Atlanta plant. In addition to the Atlanta plant facilities and its three Georgia operations at Rome, Macon, and Brunswick, The Mead Corp. has 33 other plants and mills in the United States.

Mosinee Paper Mills Co.

Trim Recovery System

Mosineee Paper Mills Co. is spending almost half a million dollars on a lime recovery system. It will enable the company to reprocess lime sludge which presently is being discarded by the mill and used by farmers as a soil conditioner. By reprocessing its lime, the amount of purchased lime required for a ton of pulp will be reduced from 630 lb. to approximately 50 lb.

Through a continuous system that begins and ends at the pulp mill, the lime sludge is fed into a large rotating kiln or oven 8 ft. and 140 ft. long. As the sludge passes through the kiln the 2000° heat brings about a chemical reaction that converts the sludge into new lime.

The system must be operated whenever the pulp mill is in operation. A 25-hp. electric motor rotates the kiln at a rate of about 1 r.p.m. per minute. An auxiliary gasoline engine will be installed as a standby unit in case of power failure.

Natural gas is used for heating the kiln. Full facilities for fuel oil use are provided as a standby unit.

S. J. Baisch Associates of Kaukauna, Wis., engineered the system. The kiln was designed and built by Allis-Chalmers Mfg. Co. of Milwaukee. General contracting for the installation will be handled by Thomsen-Abbott Construction Co. It is expected that the system will be put into operation in January, 1961.

Staff

Fred A. Haselow has joined the plant engineering staff of Mosinee Paper Mills Co. He formerly was chief engineer of Charmin Paper Mills at Green Bay, Wis.

National Container of California

Linked with the rapid industrial and population growth of the Western states, National Container Corp. of California, a subsidiary of Owens-Illinois, has dedicated its newly expanded Los Angeles corrugated box plant, the company's largest and one of the world's most efficient.

Capable of producing 4 million sq. ft. of corrugated board every 24 hr., the plant is two and one-half times the size of the facility as it existed in 1950.

Representing an investment in excess of $5 million, the 300,000-sq. ft. plant is located on a $10^1/_2$-acre site in the heart of the Los Angeles central manufacturing district and employs about 300.

It is equipped with the latest corrugated equipment, some of it developed specifically for this plant. A new corrugator, which can handle on 85-in. wide roll of paper stock, is called by its manufacturer, the Langston Co., "one of the most versatile corrugating units ever built." A second corrugator can produce corrugated board 78 in. wide.

Nekoosa-Edwards Paper Co.

Nekoosa-Edwards has named its big, new paper machine the Charles H. Reese, honoring the company's vice-president in charge of manufacturing.

Members of the board of directors and some 50 department managers attended a testimonial dinner at the Paper Inn to pay tribute to Mr. Reese who has headed the company's manufacturing operations for 25 years. Presiding at the dinner meeting was President John E. Alexander who traced Reese's career in the paper industry and presented him with a parchment scroll bearing the signatures of Nekoosa-Edwards associates who were in attendance. A cast bronze plaque was unveiled at the meeting which will be mounted adjacent to the new machine. It bears this inscription: "The Charles H. Reese. This machine is named in honor of the man who, more than any other individual, was responsible for the quality tradition which has made Nekoosa a leader in the paper industry."

The new machine, which will increase the company's paper production about 20%, is expected to begin operating by December 15.

Olin Mathieson Chemical Corp.

Sandwell International Inc., Consulting Engineers of Portland, Ore., has been engaged by Olin Mathieson Chemical Corp. to provide engineering services for a new wood preparation plant at its West Monroe, La., pulp and paper mill.

This is the first pulp mill outside western North America to change from pulpwood storage in log form to large outdoor chip storage such as is commonly used in the Pacific North-

west. Experience gained in the Northwest in outdoor chip storage is now being applied at West Monroe.

The work involves a complete new wood breakdown plant including two 12-ft. diam. by 67 ft. 6 in. long drum barkers, two 100-in. chippers and pneumatic conveying of pulpwood chips and bark.

Upon completion of the work in 1961, the new wood preparation plant will bark and chip 1450 cords of pulpwood per day and outdoor chip storage facilities will replace the large log storage piles presently located at the mill.

Oxford Paper Co.

Theodore H. Geiger, has been appointed staff administrator of the research department of the Oxford Paper Co. effective Nov. 1, 1960, it has been announced by Harold M. Annis, vice-president of research and development for Oxford.

Rayonier, Inc.

According to Russell F. Erickson, president of Rayonier, Inc., his company now has underway for completion during 1960–61 a program of special capital investments involving expenditures of approximately $30,000,000.

Announcing that the company's newest mill at Woodfibre, British Columbia, Can., would be in operation in May, 1961, Mr. Erickson declared that this new, advanced papermaking pulp mill with an annual capacity of 85,000 tons "illustrates the optimism with which Rayonier views the future of the cellulose industries."

The investment programs referred to include the new kraft-type mill; the conversion of the Grays Harbor, Wash., mill to a radically new pulping process; a sizable investment in a new venture at Grays Harbor; a new chemical plant for making a modified cellulose at the Fernandina Beach, Fla., division; plus a number of other substantial new capital investments.

Mr. Erickson declared that such an extensive program in the fields of cellulose chemistry and silvichemistry would not have been undertaken at this time without a strong belief in the sustained growth of the cellulose-using and other industries in the many phases Rayonier serves.

The Rayonier chief executive added that it was unusual for a company to be able to show a giant roll of a full-scale plant production of the type of pulp Rayonier will be making at Woodfibre, even though the completion of the plant is still six months off.

Across from the Waldorf-Astoria Hotel in New York,

Woodfibre, B. C. at base of richly timbered coastal mountains. Foreground, showing existing mill, is site for the new, years-ahead mill due on stream in May, 1961

The Canadian wood is processed and scheduled to mirror the system Rayonier will employ to manufacture the newest pulps at "the mill that doesn't yet exist", . . the new 85,000-ton plant currently underway at Woodfibre, B. C. Above, the prototype of the new, sophisticated family of new papermaking pulps—"Fibrenier," a bleached kraft in 12-ton jumbo rolls as it emerges from dry end of pulp machine at Jesup

Rayonier had a 12-ton jumbo roll of the new pulp on display aboard a flatbed truck. This was the first time that such a mommoth mill roll had ever been transported outside a pulp mill for public viewing.

The new, advanced pulp called "Fibrenier" will tour six of the nation's leading papermaking regions. The pulp, a kraft for papermaking, is a blend of three western Canadian trees; western hemlock, western red cedar, and Douglas-fir. Company technical personnel claim the new pulp, because of its blended fiber characteristics, offers the fine paper industry new sophisticated qualities of strength, formation, brightness, and opacity.

St. Regis Paper Co.

St. Regis Paper Co. announces the appointment of Ross P. Fallon as production manager of its Cornell Paperboard Products Co. Div. paperboard mill at Milwaukee, Wis., effective December 1. Mr. Fallon has been manufacturing superintendent at the St. Regis mill in Herrings, N. Y.

Winslow B. Mills, resident manager of the Carthage, N. Y., mill of St. Regis, is broadening his responsibilities to include charge of the Herrings mill.

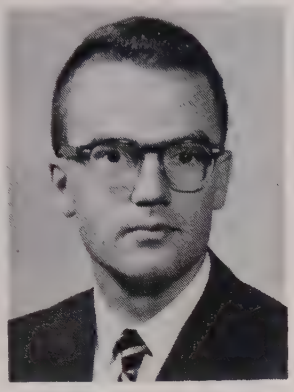
Hedgepeth Award

Charles E. Adams, assistant technical superintendent of St. Regis Paper Co.'s Pensacola pulp and paper mill, was awarded the first Hedgepeth Award for outstanding work in the fields of water and industrial waste treatment, in ceremonies at Fort Lauderdale, Fla., on November 16. The award, established in memory of the late L. L. Hedgepeth

for many years waste water consultant with the Amerian Cyanamid Company, goes to the person in Florida industry judged the most outstanding worker in the field of industrial wastes treatment. The presentation was made at the 11th Annual Joint Conference of the Florida Section of the American Water Works Association and the Florida Sewage and Industrial Wastes Association.

Staff

St. Regis Paper Co. announced that Dr. Otto Kallmes has joined the company's Research and Development Department as a research chemist. As part of the company's fundamental research program, Dr. Kallmes will carry on basic studies of the fiber networks which make up paper. He will be located in the central laboratories of St. Regis at Carthage, N. Y.



Otto Kallmes, St. Regis Paper Co.

Dr. Kallmes holds a B.S. degree in chemical engineering from Northeastern University, an M.S. degree and Ph.D. degree from The Institute of Paper Chemistry in Appleton, Wis. Prior to joining the St. Regis organization, he had carried on two years of post-doctoral research work in England with the Wiggins Teape Research Organization.

Scott

Mobile Plant

Scott Paper Co. is currently in the midst of another multi-million dollar expansion program at its Southern Division plant in Mobile.

The initial phase of the vast building program launched in July, 1959, has been concluded and contractors are currently completing the major structure which will house the firm's new paper machine and the necessary finishing equipment.

John W. McNichol, general manager of Scott's Southern Division operations, recently announced that the 2-year construction project is progressing on schedule and should be completed during the second quarter of 1961.

The expansion at the Mobile plant—estimated to cost in excess of $20 million when completed—is designed to increase papermaking capacity of the firm's Hollingsworth & Whitney specialty papers by 70,000 tons annually. It is also expected to provide approximately 300 new jobs at the mill. Scott now employs some 1650 people at its Southern Division facilities with a current annual payroll approximating $10 million.

According to McNichol, the major phase of the construction program now under way will add another paper machine to the three which are producing specialty papers for business and commercial use, and the two new tissue machines producing paper for conversion into Scott's well-known household and industrial products.

The new machine will manufacture fine quality lightweight printing papers, as well as converting specialty grades. A sheet of paper 214 in. wide will be produced.

Although construction of the paper mill building is still in progress, the basement and operating floor have been completed and contractors have already started to assemble the huge paper machine.

Nearing completion is a new 45,000 sq. ft. shipping warehouse which will accommodate eight freight cars. The design of the building provides seven bays for motor trucks and a railroad spur which runs directly into the warehouse. The building will include the most modern handling facilities

Architect's perspective of Scott Paper Co.'s Southern Division plant which is located at the northern city limits of Mobile, Ala.

for shipping and storage of Scott's high-quality line of Hollingsworth & Whitney specialty papers.

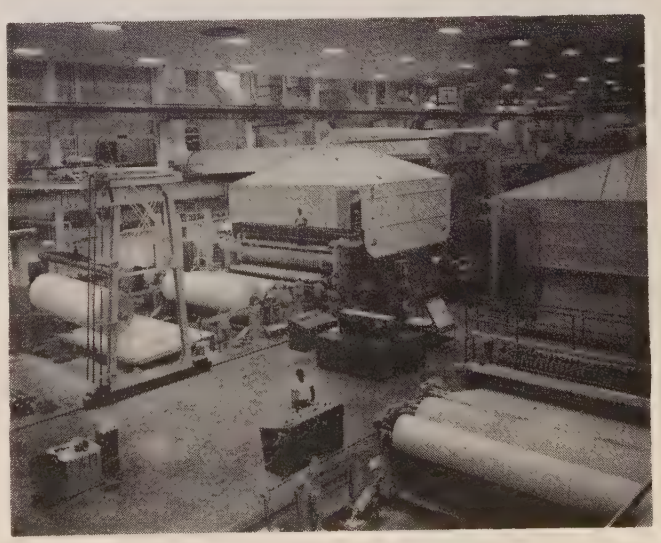
A recently completed shop and stores building houses the mill's maintenance shops and offices, as well as an inventory of thousands of different maintenance parts. These spare parts—ranging in size from miniature-size machine screws and needle valves to a spare conveyor belt weighing 6800 lb., giant machine gears and electric coils—are used by the maintenance division to keep the plant's machinery ad equipment running continuously.

Additional primary power and steam distribution facilities, including a new 250,000 lbs. per-hr. power boiler, have been completed and are scheduled to go into operation in late November.

The Scott expansion includes modernizing the specialty paper finishing room and additions to the waste clarifying system and existing pulp mill, including a new 1000-ft. long woodyard flume, three digesters, a chipper, chip screens, a chip storage silo, screens, evaporators, and causticizing equipment.

Other projects now at various stages of completion are a roll grinding building, additions to the existing locker room facilities for specialty mill employees, and a new recovery boiler.

Last year, Scott completed a building program which enabled production in Alabama of the company's widely known trademarked household and industrial products. The present expansion—designed to keep pace with the growing market for Scott's H & W bleached specialty papers—also



Scott's new tissue mill at Mobile brings to the South one of the most modern and efficient paper mills of its kind in the world. The two new tissue machines shown above can produce in a single minute a ribbon of paper 195 in. wide and up to 3000 ft. long

makes possible a further diversification of these specialty papers and increased production of current grades.

When the new facilities are in operation next year, it is estimated that the Mobile plant's expenditures for gas, water, and electricity, now at the annual rate of $2 million, will increase substantially. It is further estimated that the new operation will increase annual freight expenditures at the mill by more than $2 million, a substantial portion of which will directly benefit transportation workers in Alabama.

The new operation should also add another 500 people to the large number now engaged in harvesting and transporting pulpwood to the Mobile mill. Scott's current pulpwood expenditures are $6^1/_4$ million annually.

The Southern Division plant became a part of the Scott organization in October, 1954, following the merger of Hollingsworth & Whitney Co. with Scott. Since the merger, employment at the Mobile plant has increased by 42% and the gross annual payroll has been boosted by 86%.

Weyerhaeuser Co.

Opening of a new shipping container sheet plant at Lynchburg, Va., has been announced by Weyerhaeuser Co. An initial force of about 20 employees will produce containers from paperboard manufactured by Weyerhaeuser plants at Charlotte, N. C., and Baltimore, Md.

Educational Institutions

Lehigh University

The appointment of Dr. Albert C. Zettlemoyer as Distinguished Professor of Chemistry at Lehigh University, effective November 1, has been announced to by Dr. Harvey A. Neville, vice-president and provost.

This new professorship has been established through the 1959–60 annual-giving fund. It is the second such endowed professorship made possible through the alumni fund. Plans are under way for the establishment of a third through a $100,000 endowment being sought in the 1960–61 fund.

Dr. J. Burke Severs, head of the department of English, was named the first Distinguished Professor a year ago.

Dr. Albert C. Zettlemoyer, Director of the National Printing Ink Research Institute (right), accepts the gift of a Vandercook Universal I proof press, from E. O. Vandercook, president of Vandercook and Sons, Inc. (center). Tom Craig of Sun Chemical Corp. (left), represents J. S. Thome, president of the National Printing Ink Research Institute and vice-president of Sun, at the ceremonies. The presentation of the proof press was one of the events at the Thirteenth Annual Technical Conference at Lehigh University, Oct. 17–18

Lowell Technological Institute

A 25% volume increase in contracts for the Lowell Technological Institute Research Foundation for the fiscal year ending June 30 was reported by Dorrance H. Goodwin, executive director, at the annual meeting of the board of directors October 21 at LTI. Dollar-value of the contracts received amounted to $383,000, compared with $320,000 in the previous year. There was a great increase in the work done in electronics and physics as well as in chemistry, leather, paper, plastics, and textiles.

Geoffrey R. Broughton memorial scholarships of $100, given by companies in the paper industry, have been presented for scholastic excellence to two Lowell Technological Institute students, shown with members of the paper technology department and the dean of students Left to right are Dr. Dominick A. Sama, head of the Department of Chemical Engineering and Paper Technology, Norman Veilette, '61, Prof. Charles J. Higgins, Prof. Edward M. Engel, Peter Dubey, '62, and Dean Richard W. Ivers

Industry Suppliers

Air Reduction Co., Inc.

All activities of Air Reduction Co., Inc., in the industrial chemical field have been consolidated into a single operating unit, John A. Hill, president, announced. The three chemical divisions, Air Reduction Chemical Co., Colton Chemical Co., and National Carbide Co., have been consolidated into a new division known as Air Reduction Chemical and Carbide Co.

Mr. Hill stated that the consolidation will improve the company's effectiveness in the industrial chemical field by providing a stronger competitive front, greatly increased marketing strength, and more effective coordination of the company's activities. The sale of polyvinyl acetate emulsions will continue to be handled by the Colton Polymers Department. Vinyl monomers and other acetylene chemicals will be marketed by the Organic Chemicals Department. Both departments will market "Vinol" polyvinyl alcohol.

G. R. Milne, Air Reduction Chemical & Carbide Co.

The officers of the new division, Air Reduction Chemical and Carbide Co., are: G. R. Milne, president; B. R. Krashin, vice-president-marketing; R. T. Lund, vice-president-operating; R. A. Speck, vice-president-distribution; J. M Tinnon, vice-president-engineering; F. E. Evers, controller. C. J. McFarlin, president of Air Reduction Chemical Co., will join the corporate forward planning group.

Albany Felt Co.

Albany Felt Co. recently was host to the largest gathering of tissue mill managers and superintendents ever to attend a tissue round-table discussion at Albany. Twenty-four tissue mill operators from Maine to Washington representing mills producing 25% of total tissue production in the United States, were present at the conference held at Albany's main plant, Albany, N. Y.

This discussion was planned by Albany Felt Sales Manager James E. Smith and moderated by Laurence M. Woodside, Chief Technical Service Engineer.

Pickup felt design and the Walhstrom theory of water removal were major topics for the conference which covered subjects of interest submitted in advance by paper mill men.

Visitors to the Albany plant were given the opportunity to view the intricate feltmaking process and discuss felt operation and performance with the Albany Felt Design Group.

Because of the excellent response to these meetings, additional round tables will be planned.

Allied Chemical Corp.

General Chemical Div.

The new edition of the technical brochure on sulfuric acid by Allied Chemical's General Chemical Division features enthalpy curves which, for the first time, enable sulfuric users to calculate heat developed and final temperatures when acid is diluted with water. The profusely illustrated 40-page data book includes the latest information on uses, manufacture, properties, storage, handling, and methods of analysis. Charts have been revised for easier reference. Copies may be obtained form General Chemical Div., Allied Chemical Corp., 40 Rector St., New York 6, N. Y.

Solvay Process Div.

Plans for expansion of chlorine-caustic soda facilities at Moundsville, W. Va., were announced today by Solvay Process Div., Allied Chemical Corp. The new facilities, scheduled for completion in 1961, will increase chlorine-caustic soda production by approximately 20,000 tons annually.

Louis Allis Co.

The Louis Allis Co., Milwaukee, announced today the purchase of the Dynapar Corp., Skokie, Ill. Dynapar, founded in 1952, manufactures custom electronic equipment including preset digital controllers, transistorized clutch position compensators, length controllers, draw elongation and speed indicators and transducers used extensively in the steel, aluminum, paper, film, plastic, synthetic fiber, rubber, and other process industries.

American Instrument Co.

Identification of Phosphorescent Molecules

A new, 16-page bibliography of phosphorescent compounds listing over 200 compounds is now available as a guide to identifying solutions through their phosphorescent properties. The bibliography, published by the American Instrument Co., makers of the Aminco-Keirs spectrophosphorimeter, list the compound, its excitation and emission wavelengths, wavelength mean lifetime, concentration, solvent, excitation source, temperature, and information reference source. The compounds list and Bulletin 2334, which describes the Aminco-Keirs Spectrophosphorimeter in detail, are available without charge upon request from the American Instrument Co., Inc., 8030 Georgia Ave., Silver Spring, Md.

American Potash

Sodium Chlorate

Tow major construction projects at American Potash & Chemical Corp.'s sodium chlorate plants were completed. Production capacity at the firm's Aberdeen, Miss., sodium chlorate plant was increased 50% when an expansion project, begun last spring, went on stream. Work has also been completed on an extensive modernization program involving replacement of the sodium chlorate recovery system at the Henderson, Nev., plant.

Titanium Dioxide

Formation of a joint operation to manufacture titanium dioxide on the West Coast by American Potash & Chemical Corp. and Laporte Industries Limited was announced by Peter Colefax, chairman and president of American Potash and P. D. O'Brien, chairman of Laporte. American Potash will own 85% of the new enterprise, and 15% will be owned by Laporte Titanium Ltd., which is one of the two large producers of titanium pigments in the United Kingdom.

Initial capacity will be 25,000 tons annually, and provision will be included for further expansion. A total capital investment of $15,000,000 is estimated. The plant is scheduled to commence production in the latter part of 1962, and prior thereto field testing will be conducted with sample materials provided by Laporte.

Babcock & Wilcox Co.

Information of interest and value to engineers and designers associated with the use of tubing for corrosion resistant service, or elevated temperature and/or pressure service is included in a new data folder recently published by the Tubular Products Div. of The Babcock & Wilcox Co. The folder shows the chemical analyses of the standard carbon, alloy, and stainless tubing steels used in such service. It is cross-indexes to associate grade and ASTM Specifications with B&W's Nicloy, Croloy, and specialty tubing steels. For ready reference, the bulletin also lists the ASTM tubing and pipe specifications by number and title.

Copies of the new folder, known as Bulletin T-456, are available at no charge upon request to the Division's general sales offices at Beaver Falls, Pa.

John W. Bolton & Sons, Inc.

F. Richard Convey, General Sales Manager of John W. Bolton & Sons, Inc. and The Emerson Manufacturing Co., Division, Lawrence, Mass., has been given the added responsibilities of directing sales for the Bolton Machine Knife Division it was announced by A. L. Bolton, Jr., General Manager.

Arthur G. Schwarzenberg continues as Manager of the Machine Knife Division and C. E. Scollard as Field Sales Manager. Bolton makes knives for the pulp and paper, graphic arts, plastics, metalworking and woodworking industries.

The move was made to centralize control and coordinate all Bolton-Emerson sales activities.

F. R. Convey, John W. Bolton & Sons, Inc.

Borden Chemical Co.

Canadian Expansion

Construction by The Borden Chemical Co. (Canada) Ltd. of new manufacturing facilities for the production of polyvinyl acetate emulsions, polystyrene and acrylic emulsions, and liquid urea resins, has been announced by Gerald J. Ray, president. The expansion program includes a recently completed warehouse building, located adjacent to existing manufacturing facilities, which has doubled the company's storage area.

The project, involving an investment of one quarter of a million dollars, is now in progress, Mr. Ray stated. Canadian product additions follow the production pattern of the world-wide Borden Chemical operations. All products produced in Canada are for Canadian consumption.

Adhesive

Development of a low viscosity vegetable-based adhesive, designed specifically for adhesive spray applications in paper mill roll-heading or mill-end-wrapping operations, has been announced by The Borden Chemical Co., a division of The Borden Co. Called Borden's Cascola CS-257, the adhesive is said to atomize at extremely low spray pressures, is nonclogging, and very fast setting. It can be used on nearly all conventional spray equipment.

Cleveland Crane & Engineering Co.

A new issue of a booklet titled "Engineering and Application Data" has just been completed by the Cleveland Tramrail Division of The Cleveland Crane & Engineering Co., Wickliffe, Ohio. Helpful up-to-date information is provided for those interested in overhead materials handling. Various types of carriers, cranes, tractors, track switches, grabs, electrification are described. Detailed studies of track design, peening, and stresses are given. A large number of photographs of a wide variety of Cleveland Tramrail installations are also featured.

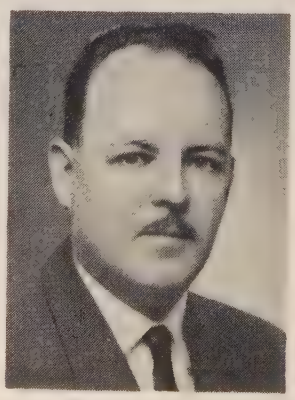
The booklet will be sent free upon request. Ask for Booklet No. 2008-Q.

Clinton Corn Processing Co.

Appointment of George H. Burns, formerly Philadelphia district manager, as sales manager for the Middle Atlantic States has been announced by A. C. Junge, Vice-President-Sales, Clinton Corn Processing Company, Clinton, Ia. His responsibility will be sales for Clinton in Southern New Jersey, Central and Eastern Pennsylvania, Delaware, Maryland and Washington, D. C., with headquarters in Philadelphia, Pa.

Combustion Engineering, Inc.

Robert A. Niemi, formerly director of manufacturing of Combustion Engineering, Inc., has been elected vice president-manufacturing, it was announced today by Joseph V. Santry, chairman of the company. In his new office Mr. Niemi will have full executive responsibility for manufacturing, purchasing, production planning, and industrial engineering. He will make his headquarters in the company's general offices at Windsor, Conn.



Robert Niemi, Combustion Engineering, Inc.

Corn Products Sales Co.

Corrugating Starch

A new starch, especially developed for corrugating adhesives, has been announced by Industrial Division, Corn Products Sales Co., 10 East 56th St., New York 22, N. Y. Designated Coragum FD, the new corrugating starch is produced by flash drying. This process, the company states, produces starch that is more uniform in particle size, composition, and moisture content. The method of drying, in a stream of heated air, is reported to eliminate completely any chance of the particles becoming overdried or case hardened due to partial gelatinization.

Practical benefits to the corrugator, according to the announcement, are (1) faster dispersion, (2) a more uniform adhesive paste, because the starch particles are more uniform, (3) easier housekeeping, because this starch produces little dust, (4) a heavier bodied adhesive in standard corrugating formulas...viscosity adjustment can be made by increasing the amount of water in the formula, (5) more uniform board ...complete dispersion eliminates lumps and grit that can cause accumulation on corrugator fingers; glue lines are better, and scrap losses are reduced.

Crane Packing Co.

Gasket Compound

A new easy-to-apply gasket compound is available for leakproofing, gasketed assemblies. It also can be effectively used to repair broken gaskets, for building up damaged, misaligned or warped flanged surfaces, or as a gasket substitute where surfaces permit. Known as Seal-Last, the new gasket compound can be used for a wide variety of industrial fluids and gas services, including water, steam, oil or water-based hydraulic fluids, L-P and natural gases, petroleum products, mild corrosives and many chemicals. Temperature range is from $-65°$ to $+400°$ F., pressures to 5000 p.s.i. It is available in two types: a soft-set variety for connections that must be periodically disassembled and a hard-set variety for permanent installations.

For complete information contact Crane Packing Co., Dept. TI-6, 6400 Oakton St., Morton Grove, Ill. (Chicago suburb). In Canada: Crane Packing Co., Ltd., Dept. TI-6, Box 134, Station C, Hamilton, Ont.

Darling & Co.

Darling & Co. announces the appointment of R. E. Kimball as eastern sales representative for the Glue Division. Mr. Kimball succeeds R. R. Jones who has transferred to Darling's Fertilizer Division at the company's headquarters in Chicago.

Dow Chemical Co.

Appointment of a specialized field salesman to serve the interests of the pulp and paper industry in the New England States and Upstate New York has been announced by The Dow Chemical Co.

E. L. Martinez, manager of Dow's Boston sales office, said Edward Novick has been transferred from Dow's Midland, Mich., headquarters to the Boston Office with prime responsibility for handling Dow products used in the pulp and paper industry.

Fischer & Porter Co.

Kimax Glass Pipe

Production and release of a new Kimax glass pipe catalog has just been announced by the Fischer & Porter Co., Warminster, Pa. Featured in the new catalog is the complete line of Kimax glass pipe, manufactured by the Kimble Glass Co., a subsidiary of Owens-Illinois, Toledo, Ohio. Fischer & Porter, national distributors of Kimax tempered glass pipe, list in their new 36-page, black-and-white catalog all sizes of

pipes, as well as various fittings, flanges, joints, gaskets, miscellaneous hardware, etc. Pipe sizes listed cover a range of quarter-inch to 6-in.

Indicating and Transmitting Rotameter

The Magnarator, a new through-flow pneumatic transmitting rotameter, is described in a six-page catalog from Fischer & Porter Co., Warminster, Pa. The catalog states the mounting of the 3 to 15 p.s.i.g. transmitter alongside the metering tube eliminates both the need for an extension and any change in direction of the fluid flow. It is explained that range, accuracy, predictability, special materials, viscosity immunity, and other characteristics of F&P rotameters are retained.

For a free copy of Catalog 10A2150, write Fischer & Porter Co., 716 Jacksonville Road, Warminster, Pa.

Freeport Sulphur Co.

Freeport Sulphur Co. announced today that it has placed in operation a new sulfur mine at Lake Pelto on the marshland shore of the Gulf about 60 miles southwest of here. To mine the deposit, the company is using its unique barge-mounted plant used originally a few miles to the north at the now-depleted Bay Ste. Elaine deposit.

Lake Pelto is the second mine which Freeport has opened this year. In June the company began commercial production at its major Grand Isle project, the world's first offshore sulfur mine, located 7 miles out in the Gulf.

General Electric Co.

Central Panels

Bulletin GEA-6334A, eight pages, describes General Electric's Pan-A-Trol panels for use with machine tools, textile machinery, pumps, materials handling equipment, presses, air conditioning, agricultural machinery, and similar equipment.

Publication explains product features and reliability and how panels are specially designed and tailored for specific control needs for engineers at G.E.'s General Purpose Control Department. Photos show various devices used in the Pan-A-Trol packaged control unit including contactors, starters, relays, switches, timers, terminal boards, and push buttons. General Electric Co., Schenectady 5, N. Y.

Longview Fibre Co. Drive

A paper machine sectional drive, the first complete drive in the industry to be controlled by transistor-silicon controlled rectifier regulators, will go into operation early next year at Longview Fibre Co., Longview, Wash. This drive is identical, in control, to that presently operating the reel section on Georgia Pacific Paper Co.'s no. 2 paper machine at Toledo, Ore.

Designed by General Electric engineers, the static-controlled system will provide precisely regulated d.c. power to drive Longview's 180-in. no. 9, fourdrinier paper machine. Operating at speeds up to 1500 f.p.m., the machine will produce 20 to 50-lb. kraft paper and 9-pt. semichemical board.

Utilization of long life static devices in the regulators will also greatly increase the unit's lifespan and cut down preventive maintenance operations.

Comprised of nine "closed-loop," regulated sections, the overall system will be integrated electrically by a signal from a master voltage reference. Each individual "closed-loop" circuit will furnish the d.c. power to drive one of the paper machine's sections. Each section will consist of a d.c. drive motor, generator, tachometer, and T-SCR regulator. Drive motors will range from 40 to 200 hp. and will be supplied power from two motor-generator sets, each powered by a 500-hp. induction motor.

Motor speeds in each section will be measured by the tachometer, whose output voltage will be compared with the machine's overall master voltage reference. The slightest difference between the two voltages will trigger an instant response in the T-SCR regulator to change the generator voltage and thus the speed of the drive motor.

General Electric is also providing a silicon controlled rectifier regulator for the no. 9 machine's winder. This SCR regulator will be interchangeable with those supplied on the sectional drive.

Heart of the new static regulators is the silicon controlled rectifier. Hermatically sealed, this semiconductor control device is impervious to adverse atmospheres commonly found in paper mills. Engineers say its application greatly reduces maintenance in the control unit and it replaces limited life components as well as those susceptible to contamination and corrosion.

Response time of the T-SCR is on the order of 10 times faster than conventional amplifiers such as rotating, magnetic, or gas tube-type regulators. In addition, the output of the regulators is not affected by variations in a.c. supply voltage.

Goulds Pumps, Inc.

To meet those requirements in the chemical process and allied industries where relatively small quantities—up to 115 g.p.m.—of corrosive chemicals or slurries, thick or abrasive, must be handled for heads up to 150 ft., two sizes of a new line of single-stage side suction open impeller pumps are now available from Goulds Pumps, Inc., Seneca Falls, N. Y.

Pumps are available in bronze fitted, all iron, all bronze 316 stainless steel and Gould-Alloy 20. Complete information available in Bulletin No. 720.5 from Goulds Pumps, Inc., 216 Black Brook Rd., Seneca Falls, N. Y.

W. R. Grace & Co.

A major plastics expansion program is announced by W. R. Grace & Co. for its Polymer Chemicals Division.

Included in the plastics expansion is a 50% increase in production facilities at the Baton Rouge, La., high density polyethylene plant and additions to the Polymer Chemicals Division's product line of a complete range of polystyrene resins as well as a full span of low and medium density polyethylene resins.

Grace's polystyrene resins are produced by Cosden Petroleum Corp., a W. R. Grace subsidiary, at Big Spring, Tex. Cosden is increasing its production capacity for polystyrene, including high-clarity, general purpose molding and extrusion resins as well as medium and high impact formulations. Polystyrene is used for a wide variety of molded packages, toys, housewares, wall tile, lighting fixtures, and appliances.

Low and medium density Grex polyethylene resins will be produced to Grace's specifications by U. S. Industrial Chemicals Co., at their Houston, Tex., plant. These resins, made from ethylene, Grace will supply to U.S.I., and for use in producing film, paper coatings, injection molded items, wire and cable insulation, pipe and packaging applications such as bottles. The density of the resins will be from 0.912 to 0.933 and the melt indices will be from 0.3 to 70.0.

Hagan Chemicals & Controls, Inc.

A new instrument that provides continuous on-stream analysis of water has been introduced by Hagan Chemicals & Controls, Inc., Pittsburgh, Pa.

The Hagan Chemonitor duplicates continuously and automatically the principles of colorimetric analysis thus determining and recording the amount of a specific component in water. A sample is piped into the instrument and mixed with reagents. When silica is present, the sample turns blue. The intensity of the color is then measured by the colorimeter and the measurement recorded on a recorder. When desired, the recorder operates an alarm or valving system.

In the zero to 300 parts per billion silica range, the Chemonitor permits detection of concentrations as low as 5 p.p.b. with ±2 p.p.b. accuracy.

Hercules Powder Co.

Hercules Powder Co. today announced the formation of a Fiber Development Department and the appointment of Forest B. Evans as manager of the newly created unit. The announcement followed disclosure by Industrial Rayon Corp. that Hercules had purchased Industrial's fibers plant at Covington, Va.

Hercules will convert the nylon section of the Covington plant to the spinning to polypropylene fibers, with an annual capacity in excess of 10 million lb. The converted facilities will be used to produce textile staple and continuous multifilament yarns from Hercules "Pro-fax" crystalline polypropylene.

Hercules Powder Co.

Charles A. Grand has been named director of sales of Hercules Powder Co.'s Virginia Cellulose Department. Arloe R. Olsen was named assistant director of sales at the same time. Both appointments are effective immediately.

Thomas E. Clark, Jr., Holyoke Machine Co.

Holyoke Machine Co.

Holyoke Machine Co. announces that Thomas E. Clark, Jr., formerly assistant treasurer and assistant to the president, has been placed in charge of sales for the territory serviced by the late George O. Trudeau.

Huyck Corp.

Huyck Felt Co. and Kenwood Mills, I td.

New developments in felts and increased services to papermakers held the spotlight in discussions at the joint marketing meeting of the Huyck Felt Co. and Kenwood Mills, Ltd., Arnprior, Ont. The meeting was held from October 25 through October 29 and included a tour through the modern manufacturing facilities at the Kenwood Mills plant in Arnprior. Following this, the formal group discussions were held at the Seigniory Club in Montebello, Que.

Group at the joint marketing meeting of the Huyck Felt Co. and Kenwood Mills, Ltd.

The classroom sessions and discussion periods gave the sales engineers and division sales managers of both companies an opportunity to exchange information on improved felt application techniques and customer service. New developments in design, treatments, and field service instrumentation were also thoroughly explained and their benefits described. The establishment of a team composed of design, research and development, sales and field service personnel was announced. This group of experienced feltmakers would bring their combined talents to bear on the analysis of the felt requirements for each machine position. In this way, not only would new developments be brought to bear promptly on special problems, but it would provide an on-the-spot technical team that would be available promptly and where needed to provide complete customer service.

A high light of the meeting was the discussion of the progress made with needled felts. Porosoft felts were reported as having been run on all types of paper machine operations with very encouraging results. Their properties of improved finish, good drainage, and added toughness have been enthusiastically received in the field. Porosoft felts were reported as standard designs on many machines were much improved performance and production are common. Great promise is held for the future of needled papermakers' felts, and development work will continue to perfect them still further.

Hector D. Wright of the E. B. Eddy Co., Hull, Que., was the afternoon guest speaker and spoke on "How Purchasing Looks at Sales." His imaginative presentation sparked interest in the group and provided additional food for thought on how Purchasing Departments and salesmen can work more effectively together.

In September of this year, a joint Huyck and Kenwood Mills Field Service Engineering meeting was held in Rensselaer, N. Y. This also provided the basis for added cooperation and interchange of information between the two groups and both groups will hold future joint meetings.

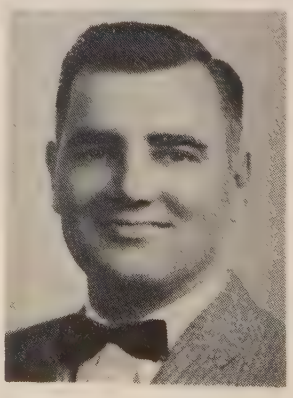
Formex Div.

Formex Co., Division of Huyck Corp., Knoxville, Tenn., announces the appointment of Warren C. Naugler as Manager of Sales and Field Service.

Huyck Felt Co.

Huyck Felt Co., Rensselaer, N. Y., and Aliceville, Ala., has announced the promotion of Rupert H. Austin, Jr., from field service engineer to felt sales engineer for Connecticut, Rhode Island, and portions of Massachusetts, New Hampshire, and Vermont. He replaces Warren Naugler who has been promoted to another division of the Huyck Corp.

Mr. Austin, a graduate of Brown University, has served papermakers in Southern New England for several years as a Huyck field service engineer. Prior to joining Huyck, he



R. H. Austin, Huyck Felt Co.

W. C. Naugler, Huyck Felt Co.

worked for Strathmore Paper Co. and the National Aniline Div. of Allied Chemical & Dye Co.

The felt cleaning selectograph, developed by Mr. Austin while serving Huyck as a field service engineer, is now being widely used by paper mills to determine recommended shut-down washing procedures for specific felt plugging problems. Used by itself, or as a companion "tool" to Huyck's newest felt cleaning bulletins, "Cleaning Papermakers' Felts" and "Mechanical Methods of Felt Cleaning," the selectograph is the first and only felt cleaning guide that tells papermakers, at a glance, what solution to employ, how long to use it and at what temperature.

Infilco, Inc.

Tank Cover

Free, informative brochure on the new Infilco "Monodeck" digester tank floating cover has just been published by Infilco Inc., manufacturers of water, sewage, and waste treating equipment. Eighteen pages in length, it gives full information of Infilco's new trussless, single-plate and pontoon floating cover including detail design, basic principles of operation, specifications, and advantages. The brochure will be mailed free upon request for Bulletin No. 6723 to Infilco, Inc., Tucson, Ariz.

Samuel M. Langston Co.

New Trademark

Samuel M. Langston Co., Camden, N. J., has adopted a new trademark, effective Jan. 1, 1961, symbolizing the role of the company's machines in corrugating or slitting and winding paper and paperboard.

Langston is the world's leading manufacturer of machinery for making corrugated shipping containers. The 60-year-old firm also produces slitters and winders used in papermaking.

The new trademark unifies four curves moving at right angles in the shape of a cross, each curve embracing a circular roll, thereby suggesting webs of paper.

Two former trademarks are replaced by the new symbol, one a cutterhead and shears, used since 1902 in connection with slitting and winding machinery; and another, a T-square and triangle used with the phrase "Leadership by Design" since 1955 for the corrugating machinery business.

Introduced with a new trademark is a new typographical version of the Langston name—a logotype in specially designed modern italics. These italics and the new trademark will also be used by Greenwood Engineering Co., Inc., Baltimore, Md., a Langston subsidiary, manufacturer of printer-slotters and folder-gluers.

Langston LEADERSHIP —BY DESIGN

LANGSTON Leadership...by design

SHEAR CUT CLEAN CUT

New trademark and logotype of Samuel M. Langston Co., above at top, replaces two below. Previously, the Camden, N. J., firm used the cutter-head and shear symbol in connection with its manufacture of slitters and winders and the T-square and triangle with machines making corrugated shipping containers

Midland-Ross Corp.

Waldron-Hartig Div.

A new, revolutionary, and simple device for automatically starting new rolls of paper and board on center winders is announced by Waldron-Hartig Div. of Midland-Ross Corp., New Brunswick, N. J.

R. J. Jacobs, vice-president & general manager of Waldron, states that the new "Waldron Method" for which patents have been applied, represents one of the most significant contributions to high-speed web handling developed in recent years.

The "Waldron Method," which consists of a low inertia cut-off device accelerated by the web itself was perfected on a 30 in wide two-spindle rotating center winder by the Waldron Department earlier this year. This unit is maintained for demonstration on different materials to web process converters and mills. Grades of paper from lightweights to heavy chipboard have been started on new cores at speeds to 2000 f.p.m. without fold back or wrinkles so that waste at the core is a bare minimum. The "Waldron Method" core starting device can readily be adapted to existing two or three-spindle rotating-type center winders, and inexpensive conversion units are available.

J. O. Ross Engineering Corp.

The J. O. Ross Engineering Division of the Midland-Ross Corp. offers a new "Dryjector" unit for improved ventilation of vapor pockets formed by the sheet, drier, and felt rolls. Improved ventilation of these pockets results, of course, in a more uniformly dried sheet. The Ross "Dryjector" unit forces fresh, heated air into the centers of the pockets, dispelling moist vapors toward the edges of the sheet and into the exhaust system.

For additional information on the new "Dryjector" unit, write to the J. O. Ross Engineering Div. of the Midland-Ross Corp., 730 Third Ave., New York, N. Y.

Minneapolis-Honeywell Regulator Co.

New 48-page ElectroniK Recorder catalog highlights new modular design features, the quick changing 2 to 24 point ElectroniK Universal Multipoint recorder, and other ElectroniK strip and circular chart recorders and precision indicators. To obtain this complete, highly illustrated book, write for Catalog C 15-1a, Minneapolis-Honeywell Regulator Co., Wayne & Windrim Ave., Philadelphia 44, Pa

Mixing Equipment Co., Inc.

The Mixing Equipment Co., Inc., Rochester, N. Y., and Stockdale Engineering Co. in England have announced the formation of a new company in Poynton, Cheshire, England, to manufacture and distribute the complete line of "Lightnin" industrial mixers in the European market. The new company will be known as Lightnin Mixers, Ltd.

Monsanto Chemical Co.

A new film-forming styrene copolymer latex, to coat paper and paperboard for drinking cups, disposable containers, and food packages, has been introduced by Monsanto Chemical Co.'s Plastics Division.

Designated Lytron 6A, the new material is said to provide a continuous, nonblocking, clear coating with excellent resistance to hot and cold liquids and grease and oils. It is odorless, tasteless, and nonyellowing.

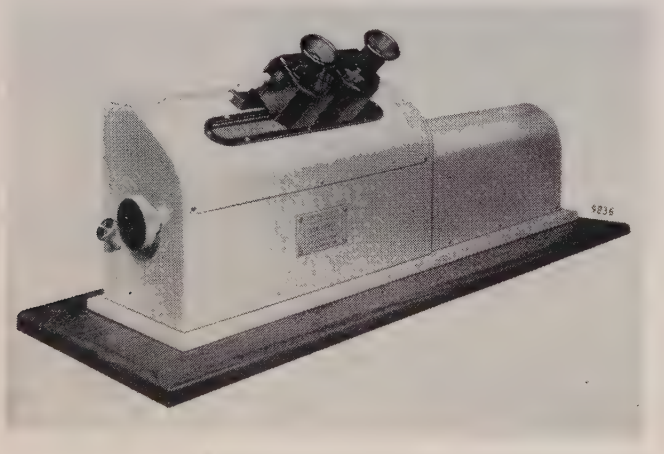
A white water emulsion, Lytron 6A is exempt from the provisions of the Food Additive Amendment for coating paper cups, plates, and other single service containers used in the home. Monsanto reported that the Food & Drug Administration is expected shortly to confirm its use for general food packaging.

Mt. Hope Machine Co., Inc.

New web viewer visually stops and permits inspection of moving materials to inspect moving textiles, printed cloth, paper, plastic, foil, and other materials while machines are operating at normal production speeds. The Mount Hope Web Viewer is a unique instrument available from Mount Hope Machine Co., Inc., Taunton, Mass., manufacturer of web handling equipment for the textile, paper, and plastics industries.

This precision optical device provides closed-up of full-width examination of materials without interrupting production schedules. Although the viewer seems to stop moving materials, the illusion is created by an oscillating mirror system. As the plain or printed material passes the Web Viewer, the mirror system, which is automatically synchronized to the speed of the range, scans a given section, causing it to appear stationary. As each section passes from the observer's sight, the mirror system returns to the beginning of the stroke and "picks up" visually the next section to be examined.

The Mount Hope Web Viewer may be adjusted to examine patterns of different repeat lengths. This unique device permits careful inspection of colors, structure, or register. With the mirror system operating at 400 cycles per minute,



Mt. Hope web viewer

speeds at which the material may be viewed are determined by multiplying the repeat length by 400. Materials running at speeds up to 1500 f.p.m. can be examined in 45-in. long sections. The retractible 4× binocular permits closer inspection of any local area within the section.

Complete information regarding the Mount Hope Web Viewer may be obtained from the Mount Hope Machine Co., Inc.

D. J. Murray Mfg. Co.

Schnyder Tunnel Barker

A. W. Plier, president, D. J. Murray Manufacturing Co., Wausau, Wis., announces that his company has been granted sole sales and manufacturing rights by Combustion Engineering, Inc., of Windsor, Conn., for the newly developed Schnyder tunnel barker. Combustion Engineering, Inc., holds the patent rights for the new barker which was developed by A. T. Schnyder, consulting engineer for Lummus Co., a subsidiary of Combustion Engineering, Inc. The Schnyder tunnel barker represents an entirely new concept in bark removal, utilizing the working parts of the conventional type trunnion barking drum, except the revolving drum is replaced with an "open" scroll sweeping the circular tunnel that supports the logs. Barking action is principally by friction and impact against the concrete tunnel wall. Designed for barking commercial size pulpwood ranging from 4 to 10 ft. in length and 4 to 24 in. diam., the Schnyder tunnel barker is 12 ft. diam. by 48 or 72 ft. in length, depending upon the number of scroll sections, the latter being 24 ft. in length.

Nalco Chemical Co.

A broad spectrum of cationic and nonionic surface active agents, ranging from fatty nitrogen derivatives to polyether alcohols are described in a four-page booklet available from Nalco Chemical Co. Among other chemicals discussed are fatty imidazoline diamines, fatty amidomonoamines, fatty amidodiamines, quaternary ammonium chlorides, oxyalkylation products, and colloidal silicas. Physical characteristics of the chemicals and some of their uses are included. Bulletin K6 may be obtained by writing to Nalco Chemical Co., 6216 West 66th Pl., Chicago 38, Ill.

National Starch & Chemical Corp.

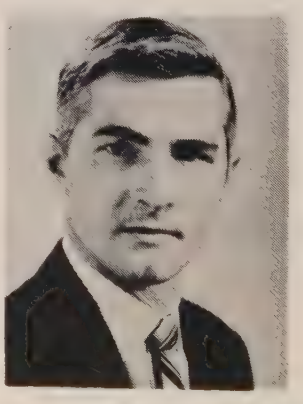
New Polymer Plant

National Starch and Chemical Corp.'s 14 million lb. polyvinylidene chloride resin plant at Meredosia, Ill., is now "on stream" in commercial production of Resyn 3600, an aqueous dispersion of vinylidene chloride copolymer. While under development for more than 5 years, Resyn 3600 was only revealed commercially in May of this year. This resin offers possibilities for packaging, surface coating, and construction material, due to its extremely low water vapor transmission rate, its barrier properties which resist the permeation of organic vapors and gases such as oxygen, nitrogen, and carbon dioxide, as well as its exceptional chemical, grease, and oil resistance properties.

National Starch and Chemical Corp.

Staff

Richard W. Reiter of the Resin Div. of National Starch and Chemical Corp., has been promoted to the position of laboratory manager of the Resin Development Group, it was announced by A. G. Battaglia, product manager, Structural Products Division, National Starch and Chemical Corp.



R. W. Reiter, National Starch & Chemical Corp.

L. J. Hickey, National Starch & Chemical Corp.

Mr. Reiter, a graduate of Wheaton College, was formerly in charge of Product Applications Development for the Resin Research Group. Mr. Reiter will continue to direct phases of this work, and he will, in addition, be responsible for development and service work in the paint, coatings, binders, and other resin markets.

Lawrence J. Hickey has been promoted to Senior Development Engineer in the Paper Converting Group at National Starch and Chemical Corp. of the Paper Division.

Orr Felt & Blanket Co.

M. B. Orr, president of The Orr Felt and Blanket Co., Piqua, Ohio, announced today that company engineers are preparing to install approximately $400,000 worth of new felt manufacturing equipment ordering some months ago. This includes the very latest and most modern needling machines, as well as drying and other equipment. In order to provide room for the new machinery, the company is discontinuing the manufacture of bed blankets and apparel fabrics, thus making available space needed for felt operations.

Pfaudler-Permutit, Inc.

Research and Development Center

The Pfaudler Co., a division of Pfaudler Permutit, Inc., formally announced today its plans to build a three-quarter-million-dollar Research & Development Center.

The company will build in Henrietta, a suburb of Rochester, N. Y., providing a selected site is rezoned for industrial use.

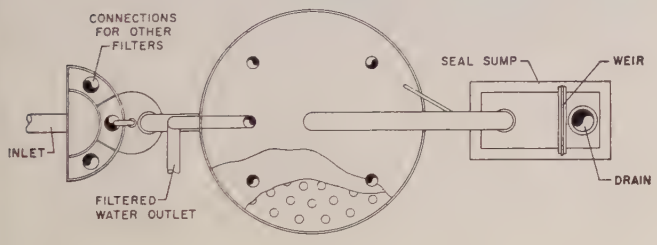
In addition to the Research Department the center will also house the Engineering Service and Product Development departments consisting of product applications, project engineering, design services, and engineering test center sections.

The technical center will contain an auditorium to accommodate over 100 persons. It will be used for technical meetings, corporate meetings, customer corrosion seminars, and other company functions.

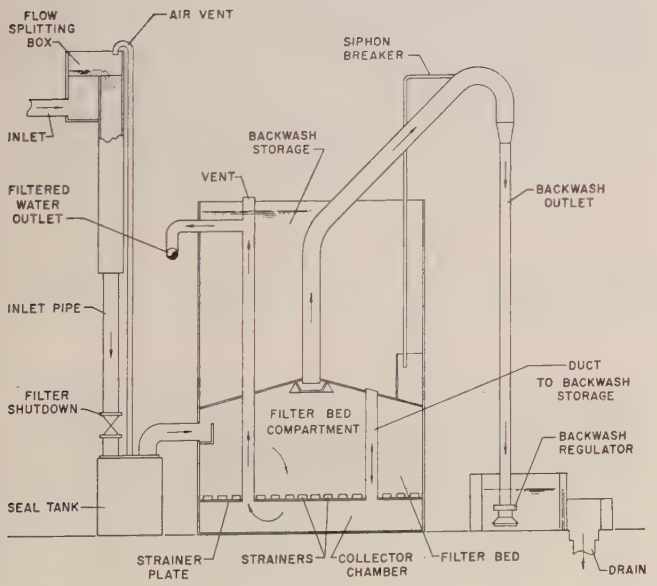
A modest research library will be included to replace the small, one-room library at the company's present research building.

There will be three major areas of research conducted in the center. They are ceramic, metallurgical, and organic.

Automatic Valveless Gravity Filter



PLAN



ELEVATION

Tray Deaerators

A new line of tray deaerators, custom engineered to give maximum corrosion protection in boiler feedwater systems, has just been introduced by The Permutit Co., division of Pfaudler Permutit Inc.

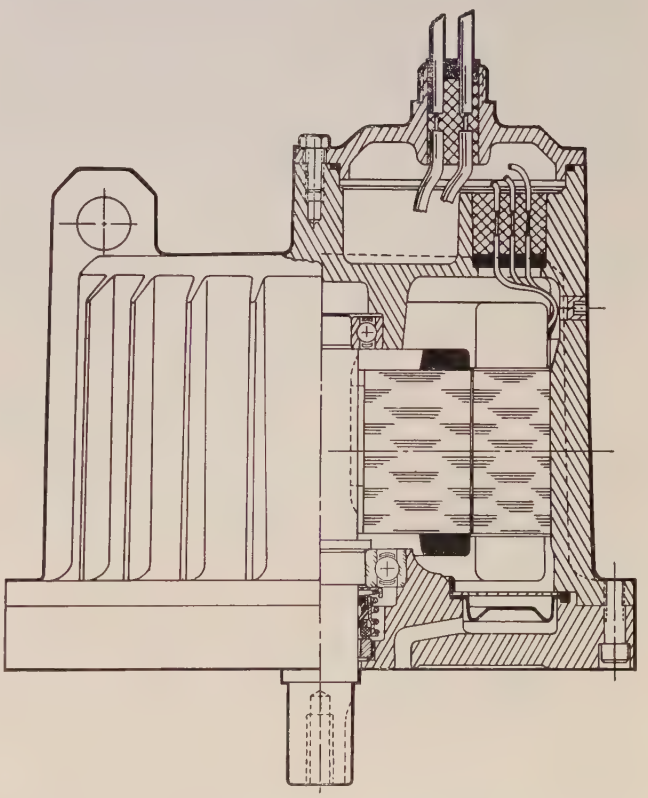
The Permutit tray deaerators are designed to provide highly effective protection against corrosion of boiler tubes, internals, feedwater lines, auxiliaries, and condensate return lines by removing noncondensable corrosive gases from the boiler feedwater. Effective deaeration of boiler feedwater is guaranteed to specified low quantities of gases (0.005 ml. oxygen per liter of water and zero CO_2) regardless of variations in load or amount of gases initially present—and the advanced counterflow design will meet guarantees at any load from 0 to 100% of rating with as little as 30°F. temperature rise at any steam pressure from $^1/_2$ p.s.i.g. up.

Valveless Filter

The Permutit Co. has introduced a new gravity water filter for municipal and industrial use that meets most criteria in these fields, including probably the two most important: very low initial cost versus designed performance, and fully automatic operation requiring no power or operator. To achieve this, Permutit built its new design around a very old device: the siphon. Combined with a filter bed in a compartmented tank, this siphon performs the backwash operation automatically; and there are no pumps, valves, gages, or manual or electric controls anywhere in the unit. Actuation of the backwash cycle is accomplished at exactly the optimum moment without any outside aid, the filter cannot over- or underwash, and backwash or rinse water cannot be accidentally run to service. The unit operates on a loss-of-head and can be used wherever gravity feed is feasible.

Reliance Electric & Engineering Co.

A completely new line of submersible a.c. motors has been introduced by Reliance Electric and Engineering Co.,



Cutaway view of new pressureproof submerisible a.c. motor shows reconnectable dual-voltage leads in chamber at top right; neoprene diaphragm with built-in O-ring at bottom right; running face shaft seal at bottom center

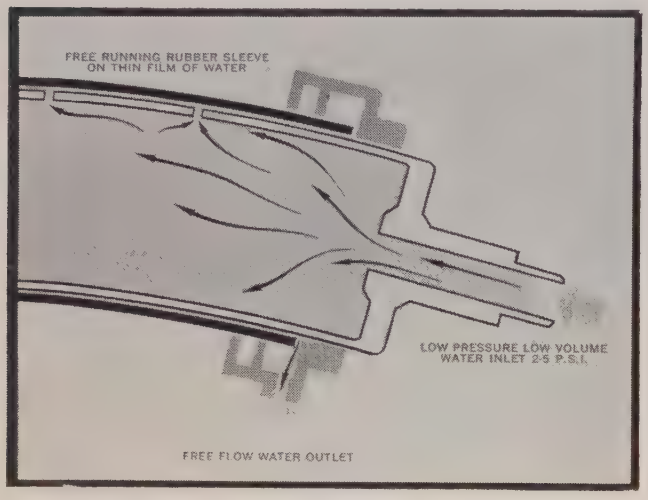
Cleveland, Ohio. The new pressureproof motors, especially designed for close-coupling to centrifugal pumps operating in any depth of water, oil, or liquid chemicals, are now available in sizes from $^1/_2$ through 40 hp. for operation from polyphase power sources, and from $^3/_4$ through 5 hp. for single-phase connection. The new motors are rated at 55°C. temperature rise for 30-min. duty in 40°C. air, and for continuous duty in 40°C. liquids.

Rodney Hunt Machine Co.

Bow Spreader Roll

The Aquatrol Expander (patent pending), a unique, new bow spreader roll, is the subject of a 4-page bulletin just issued by the Rodney Hunt Machine Co. of Orange, Mass. This roll is now in successful operation in both textile plants and paper mills.

The design of the new roll embodies an entirely new



Cross-section diagram of the Aquatrol Expander, the new bow spreader roll developed by the Rodney Hunt Machine Co. Water is shown pasing through the hollow shaft of the roll and through the holes with which it is perforated to form a film of water on which the rubber sleeve floats. Water escaping from the ends of the sleeve is gathered by the collector rings and drained off

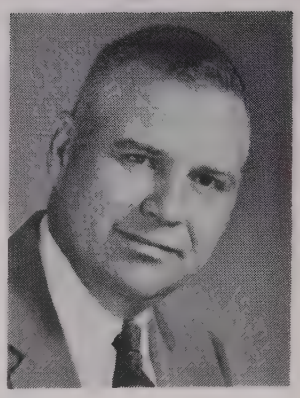
principle of operation. With only one moving part—in contrast to the many moving parts of the conventional bow roll—the Aquatrol Expander operates with practically no friction. The single moving part is a rotating rubber sleeve that floats on a film of water to give uniform, smooth, even spreading action over every increment to face width.

In addition to describing the economic benefits and design features of the roll, the new bulletin incorporates a handy form for requesting a quotation on an Aquatrol Expander. Copies of the bulletin may be obtained without obligation by writing to Industrial Roll Div., Rodney Hunt Machine Co., Orange, Mass., and requesting Bulletin R-960.

Sandy Hill Iron & Brass Works

Amasa Howland, direct descendent of one of the country's oldest papermaking families, has recently joined the sales engineering staff of The Sandy Hill Iron and Brass Works as their sales representative in Michigan, Wisconsin, and Minnesota.

He is a great, great grandson of Stephen Howland, who built a paper mill at Kane's Falls in Washington County, N.Y. in the early 1800's. In 1844 this same Stephen Howland erected the first manila paper mill in the United States at Sandy Hill, N. Y., known since 1910 as Hudson Falls.



Amasa Howland, Sandy Hill Iron & Brass Works

J. E. Hargreaves, Scott Testers (Southern), Inc.

Scott Testers (Southern), Inc.

The appointment of John E. Hargreaves as president of Scott Testers (Southern), Inc., with offices in Spartanbrug, S. C., was announced today by David C. Scott, Jr., president, Scott Testers, Inc., of Providence, R. I. Mr. Hargreaves succeeds James M. Scott, who died unexpectedly June 19, 1960. Prior to his appointment, Mr. Hargreaves was manager for Scott Testers (Southern).

Sprout, Waldron & Co., Inc.

Screw Conveyors

The availability of a new bulletin (83-A) describing standard, and industrial gas-tight screw conveyors has been announced by Sprout, Waldron & Co., Inc.

Double Agitator Mixers

The availability of a new bulletin on continuous double agitator mixers is announced by Sprout, Waldron & Company, Inc., Muncy, Pa. The bulletin describes design details and gives specifications on 11 different sizes. Ask for Bulletin 131-B.

A. E. Staley Mfg. Co.

Two promotions at the A. E. Staley Manufacturing Co. were announced by Robert L. Schuerman, manager of the company's paper industry sales department serving the paper, corrugated, building materials, and related industries. Herbert L. Roszell, Jr., was promoted to manager of dextrin and adhesive products, and Thomas C. Garren was promoted to sales service supervisor.

Stauffer Chemical Co.

Stauffer Chemical Co.'s Consolidated Chemical Industries Division is building a liquid aluminum sulphate plant at Counce, Tenn., on a 172-acre tract adjacent to the new paper mill of Tennessee Pulp and Paper Co. Engineering has been completed by Stauffer. Construction is now under way and the plant is scheduled to be on stream about Feb. 1, 1961. While this is Stauffer's first alum plant in the Southeast the company operates seven other alum plants serving the Southwest and Western areas with all grades of aluminum sulfate, both liquid and granular.

Stebbins Engineering & Mfg. Co.

A new laboratory and facilities for processing special proprietary acid-resisting compounds are now under construction adjacent to the main building of the Stebbins Engineering and Manufacturing Co. at Watertown, N. Y. The reinforced concrete, steel, and cement block structure, containing approximately 15,000 sq. ft. of floor space on two floors, will be completely fireproof and partially air-conditioned. The L-shaped building is built against a hillside, with receiving on the upper floor and shipping from the

Sketch of the new laboratory being built by Stebbins Eng. & Mfg. Co.

lower, to take advantage of gravity flow between floors in the processing operations. Research and testing facilities now in the main building will be replaced and substantially extended by the new building.

According to E. F. Tucker, president, the building is expected to be completely enclosed before Christmas and partially occupied in the spring of 1961. This is the third major expansion for Stebbins at the Watertown site since erection of the main building in 1937.

Stowe-Woodward Inc.

Wisconsin Division

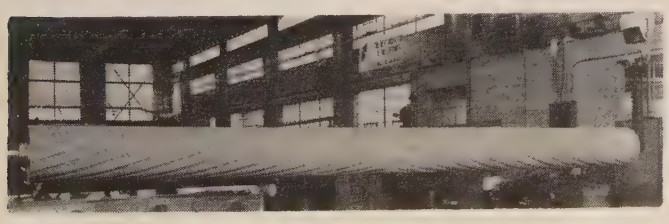
The Wisconsin Division of Stowe-Woodward, Inc. has been enlarged with the opening of a new and modern 32,300 sq. ft. manufacturing plant. Located in Neenah, Wis., on Route 41, it will be the third Stowe-Woodward plant to offer suction press roll covering service to its customers. The firm also maintains divisions and manufacturing plants in Newton Upper Falls, Mass., and Griffin, Ga. The Wisconsin Division was established in 1954. Customers in the Fox River Valley and the Mid-Western States will be serviced by this division.

Suction Press Rolls

A catalog page which describes the properties and advantages of its suction press roll coverings has been made available for general distribution by Stowe-Woodward, Inc. Chemical and temperature resistance, hardness range, pressures, and cover thickness are data that have been included. Copies are available through the Product Service Dept. of Stowe-Woodward, Inc. Interested mill men may write to the Newton, Mass.; Neenah, Wis., or Griffin, Ga., division for their copy.

Cutter Roll

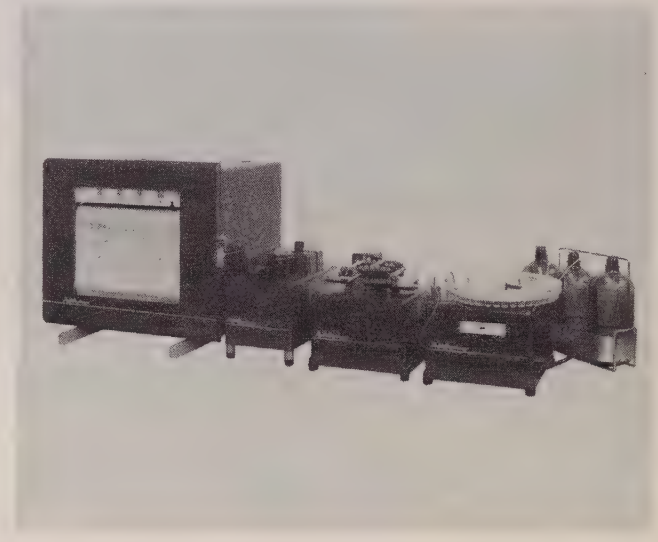
A grooved cutter roll, for the world's largest duplex cutter, was covered by the Massachusetts Division of Stowe-Woodward, Inc. It measures 16 in. diam. with a 233 1/2-in. face length. The Clark-Aiken co. is the manufacturer of the duplex cutter, for the new Continental Can plant in Augusta, Ga.



Grooved cutter roll covered by the Massachusetts Div. of Stowe-Woodward

Rubber Guide

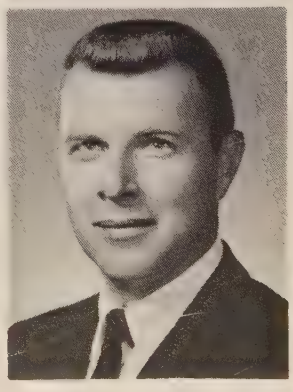
Stowe-Woodward, Inc. has issued a product bulletin on the properties and limitations of synthetic rubbers and plastics. The bulletin was prepared by the R&D Department and includes 12 pages of data on the major synthetic rubbers and plastics. GR-S, Neoprene, Nitriles, Thiokol, Silicones, Polyvinyl Chloride, Polyesters, Polyethylene, Phenolics, Teflon and Kel-F are described together with charts which indicate the maximum concentrations and highest temperatures at which specific materials can be used with them. There is also a chart on the chemical resistance of synthetic rubber and plastics. The bulletin has been made available for general distribution and interested mill men should write to the Product Service Department, Stowe-Woodward, Inc., Newton, Mass., for their copy.



Technicon AutoAnalyzer*, an electronic system of continuous automatic chemical analysis, was adapted for use with the TCM method for determination of sulfur dioxide in the atmosphere in Nashville Community Air Pollution Study conducted by U. S. Public Health Service. Developed and manufactured by Technicon Controls, Inc., Chauncey, N. Y., robot chemist made 130 determinations a day, 7 days a week, for more than a year. Public Health Service officials reported sensitivity of 0.005 p.p.m. and reduction of analytical man-hour requirements of 75% by automating the process

Virginia Smelting Co.

The appointment of Arthur C. Waldron as New England district sales representative for the Virginia Smelting Co. was recently announced by J. A. Weatherford, manager of the Industrial Chemical Sales Department.

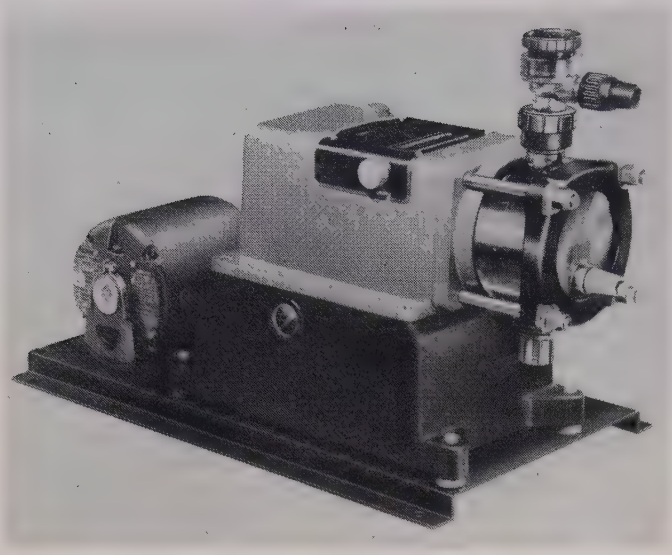


A. C. Waldron, Virginia Smelting Co.

Wallace & Tiernan, Inc.

Low-Capacity Metering Pump

A low-capacity metering pump designed for flexibility in industrial applications has just been released by Wallace &



Wallace O. Tiernan low capacity metering pump

Tiernan, Inc. Interchangeable heads of Tyril or Penton plastics with a variety of trim materials mean custom metering of a wide range of corrosive liquids. The pump is available with a single head (Series A-747) or double heads (Series A-748). Maximum capacities are 250 and 500 g.p.d. respectively. Maximum pressure is 100 p.s.i. for both models. The dual-head model has separate stroke-length adjustment and indication for each head. Thus, two chemicals can be proportioned simultaneously, or twice the volume of the single model can be handled with one pump. Maximum capacity per head of 250 g.p.d. can be reduced to 140, 80, or 40 g.p.d. by simple belt and pulley changes.

Stroke length is adjustable over a 10:1 range while the pump is operating. Pumping is by positive-displacement diaphragm action. There are no stuffing boxes, shaft seals, or packing glands to leak. Short stroke length and slow stroking speeds assure long diaphragm life. Write Wallace & Tiernan, Inc., 25 Main St., Belleville 9, N. J., for more information.

Anode for Cathodic Protection

A new form of anode, for cathodic protection systems using impressed current, was announced by Electro Rust-Proofing Corp., a division of Wallace & Tiernan, Inc., Belleville, N. J.

The new anode, known as PTC-Clad, is a composite conductor which combines the high-current-carrying capacity of copper, the anodic-passive properties of tantalum, and the nonsacrificial qualities of platinum. Because of its wire form and its unique combination of electrochemical properties, the PTC-Clad Anode makes possible the use of platinum for anodes which formerly would have been economically or technically impractical.

Information on the use of the new PTC-Clad anode for cathodic protection systems is available from Electro Rust-Proofing Corp., 25 Main St., Belleville, N. J.

Walmsley (Bury) Group, Ltd.

The Walmsley (Bury) Group, Ltd., Bury, Lancashire, England, world-renowned builders of high-speed paper machinery, have now been licensed by Clupak, Inc. to build the machinery for making Clupak extensible paper. Gerald E. Amerman, president of Clupak, Inc., New York, N. Y., and Percy Holland, managing director of Walmsley's, signed the license for their respective companies.

Walmsley's is the fourth machinery company licensed by Clupak, Inc. to build and install extensible paper machinery, others being: Beloit Iron Works of Wisconsin, The Sandy Hill Iron & Brass Works of Hudson Falls, N. Y., and Mitsubishi Heavy Industries Reorganized, Ltd. of Japan.

General

Circular Slide Rule

General Industrial Co. has started production on a handy circular slide rule for engineers and for other plant and office executives. Any executive who must perform simple calculations will find this convenient, pocket-size calculator extremely useful in his work.

Operation of the rule is simple and the results are accurate. To multiply, divide, and find proportions is easy and exceptionally fast with this convenient circular rule. Complete easy-to-follow instructions will be included with each slide rule.

For a free circular slide rule write on your business letterhead to General Industrial Co., 1788J Montrose Ave., Chicago 13, Ill., and be sure to mention the name of this magazine. To those who do not qualify as an engineer or other business executive to receive a free slide rule, General Industrial Co. will be pleased to send one for 50¢.

Personnel Placement

Over half the job requests directed to The University of Michigan placement office by business, industry and government sought technically trained personnel during 1959–60.

Engineers led the lot, representing 33% of the requests, the annual report of the Bureau of Appointments and Occupational Information points out. Actually engineer requests dropped about 4% from the 1958–59 figure, but queries for health service personnel increased by the same percentage.

The Bureau's General Division scheduled interviews for 174 companies and organizations across the country and handled 18,481 requests.

Average salaries accepted at the bachelor and master degree levels were up over 1958–59, Bureau figures show. Beginning salaries for bachelor's degrees averaged $461. The previous figure was $406. Master's degrees attracted monthly salaries of $522, compared with $518 for the previous year.

Engineering placements reported beginning salaries of $524 for bachelor's degrees compared to the previous $508. Salaries at the master's level for engineers rose from $598 to $655.

Salaries accepted at the doctoral level in the sciences and liberal arts depended on individual interests, accomplishments, and other variables, but ranged between $650 and $800 monthly. The previous range was between $653 and $750.

Areas of greatest demand, according to number of requests received are electrical and mechanical engineering; in natural sciences—forestry, bacteriology, biology, and biochemistry; in physical sciences—chemistry, mathematics, and physics; in social sciences—sociologists in case work recreation studies, and psychiatric-case work in health service —nursing, medical technology, physical and speech therapy, industrial hygiene, and dietetics.

Among professional degree holders in areas of business and industry city planners got the greatest call. Among the business trained people, those schooled in market research analysis, management training, purchasing, sales training, technical sales, and accounting won greatest demands.

In communications arts, graduates with training in technical and industrial journalism and those with knowledge of printing, publishing, and editorial work received greatest demands.

Wood Production Study

A group of firms interested in the progress of the forest products industry in the Southeastern United States has authorized a comprehensive study by Battelle Memorial Institute of wood production in the region. Announcement that the study had begun at the Columbus, Ohio, research center was made by Dr. Frank C. Croxton, who will direct the project.

The need for a cooperative research effort was recognized by the Southeastern Technical Committee of the American Pulpwood Association, and the Association will coordinate the study, currently on a three-year schedule.

One purpose of the project, according to Dr. Croxton, will be to study existing methods of producing wood and, by applying modern techniques of research and analysis, to discover ways for more efficient harvesting and transportation of forest products from the stump to the consumer. If the information developed suggests usable technological improvements, woodland owners, loggers, dealers, consumers, and the general public stand to benefit, he observed. "Indeed the economy of whole communities in the Southeast that are heavily dependent on the forest products industry could be improved."

Battelle specialists will study the use of manpower and equipment to determine how these factors influence wood production and transportation to the user. Since weather conditions greatly affect operations of the forest products industry, the effects of weather on men and machines will be considered in detail.

Dr. Croxton pointed out that it is difficult at this initial stage of the project to describe more specifically Battelle's approach to the problem. The study could, he indicated, result eventually in recommendations for better use of existing wood harvesting and handling equipment or in improved designs for such equipment.

At present, a team of Battelle specialists, including economists, industrial engineers, mechanical design engineers, and operations research experts, is gathering information on many facets of the problem. Much of the information will have to come from field work. The region under study includes Alabama, Florida, Georgia, North Carolina, South Carolina, Tennessee, and Virginia.

Fertilizer for the Forestry Industry

A fertilizer which can be applied directly to the bare roots of tree seedlings has been developed by W. R. Grace & Co. The new fertilizer is a magnesium ammonium phosphate compound, composed of 8% nitrogen, 40% available phosphate, and 24% magnesium oxide (8-40-0). Developed especially for the forestry industry, this compound may be applied at a heavy rate.

This nonburning fertilizer is one of a new family of metal ammonium phosphate compounds produced through an exclusive process at Grace's Washington Research Center in Clarksville, Md.

Field tests have indicated a second metal compound, ferrous ammonium phosphate (7-35-0), to be equally effective in some forestry applications. However, at this time it is primarily recommended for use in nursery beds. When required, a mixed fertilizer may also be produced using the (8-40-0) grade as a base which will employ all of the essential elements needed for plant life.

Solids Determination in Aqueous Pigment Slurry

Solids analysis of pigment slurry to $\pm 0.3\%$ accuracy in less than two minutes has now been achieved by radio frequency spectroscopy. This advance is announced by research scientists of the Ridgefield Instrument Group, Schlumberger Corp., Ridgefield, Conn.

Applicable to paper, water-based paints, inks, starch or cereal solutions, colloidal clay suspensions, and many other aqueous systems, the instrument, designated the Model 104 Analyzer, serves as a laboratory, production, and quality control tool.

Grocery Bags

Reduction of the number of standard grocers' paper bags from the current 33 to 27 has been proposed to the paper bag industry in a revision of the industry's simplified practice recommendation, according to the Commodity Standards Division, Office of Technical Services, Business and Defense Services Administration, U. S. Department of Commerce.

The revision concerns Simplified Practice Recommendation R42-53 *Grocers' Paper Bags* and has just been circulated to representative industry organizations for consideration and comment or approval. The revision was requested by the Paper Bag Institute, Inc., to bring the Recommendation in line with current usage. Changes include the elimination of eight sizes and the addition of two new sizes of bags that are already in general use by the trade.

Copies of the recommended revision are available on request from the Commodity Standards Division, U. S. Department of Commerce, Washington 25, D. C.

Safety Training Course

An effective, low-cost safety training course for industrial foremen has been developed by the National Safety Council.

Written by training expert Glenn Griffin of the University of Michigan's Bureau of Industrial Relations, the course consists of a series of six text booklets entitled "Men and Motives in Safety Supervision," and a manual for discussion-group leaders.

Each text booklet is for a one-hour training session for foremen. The leader's manual tells how to set up meetings and apply the material to individual plant situations.

The course offers practical instruction on ways a foreman can better understand his men and work with them toward safer, more efficient work practices. "Griffin's style is clear and down-to-earth," according to the National Safety Council.

Further information about "Men and Motives in Safety Supervision" is available from the Council, 425 N. Michigan Ave., Chicago 11, Ill.

Turbine Re-aeration Proceeding Apace

Equipment for replacing dissolved oxygen in the waters of the Fox and Wisconsin rivers is being installed at a steady pace by pulp and paper mills, according to State pollution control authorities. Theodore F. Wisniewski, Director, Committee on Water Pollution, reported that progress in turbine reaeration has been substantial, with full cooperation from a majority of the industry.

About a year ago, turbine re-aeration was already in use at four out of five strategic sites on the Fox and at five out of 16 such sites on the Wisconsin. During the summer of 1960 turbine re-aeration has been experimentally installed at De-Pere, the fifth strategic site on the Fox. Meanwhile all four mills previously operating aerated turbines have substantially expanded the capacity of their equipment to add dissolved oxygen to the Fox.

On the Wisconsin River there are now six installations. At five other sites, re-aeration equipment is either being tested or actually installed for use. Three of last year's installations are expanding their re-aerating capacity. Practically all of the other Wisconsin River mills are actively working on plans for experimental re-aeration in the near future.

Mills having turbines and grinders vented for re-aeration of the Fox River are: Kimberly-Clark Corp., Kimberly; Thilmany Pulp & Paper Co. jointly working with the City of Kaukauna Utility and Green Bay & Mississippi Canal Co.; Combined Locks Paper Co.; and Chairman Paper Products Co., Little Rapids. Experimental installations have been

made this summer at DePere by Nicolet Paper Corp. and Beemster Electric Co.

On the Wisconsin River, mills using turbines equipped for re-aeration are: Rhinelander Paper Co. working with Wisconsin Public Service Corp., Hat Rapids; Marathon Div. of American Can Co., Rothschild; Consolidated Water Power & Paper Co., Biron and Wisconsin Rapids; and, Nekoosa-Edwards Paper Co., Centralia and Port Edwards. Mills in the stage of testing and installation include: Tomahawk Pulp Co., King's Dam; Owens-Illinois Div., Grandmother Dam; Consolidated and Whiting-Plover Paper Co., Stevens Point; Nekoosa-Edwards, Nekoosa.

Packaging Firms Promote American-European Cooperation

Packaging Consultants, Inc., has opened a European office in Paris with Pierre J. Louis, director of the French Packaging Institute and internationally known packaging consultant, as manager. Packaging Consultants has also been named as the United States Office of the French Packaging Institute with Thomas P. Wharton, president of Packaging Consultants as manager.

Under this arrangement, each organization will encourage liaison between two packaging markets. According to Mr. Wharton, this provides a much needed channel of communication, for American firms in the packaging field who are interested in starting production in Europe, surveying of cultivating European markets, granting or obtaining license or patent agreements, developing mergers or working relationships, or finding agents or representatives throughout Europe.

Historic Industry Relics Recovered

Crown Zellerbach Corp. recently donated an historic grindstone to Portland, Ore.'s Forestry Building.

The 1600 lb. hand-chiseled, sandstone relic played a significant role in the development of the infant pulp and paper industry in Washington and Oregon three-quarters of a century ago.

It was originally installed at the Columbia River Paper Co. mill, now Crown Zellerbach's Camas division, in 1885 and ground the first wood pulp ever produced on the Pacific Coast. A fire ravaged the Camas mill in 1886 and the stone, along with two others, was purchased by a pulp mill on Youngs River east of Astoria, Ore. There, the stones again performed an historic function producing the first groundwood pulp in Oregon.

The stones seemed doomed to historical oblivion when the Youngs River mill ceased operations in 1904, after 17 years of operation. The mill's grinding machines were sold to the Willamette Pulp and Paper Co., later becoming Crown Zellerbach's western division. The stones, however, were abandoned and very soon the millsite and stones were covered by second growth timber.

This timberland eventually became part of Crown Zellerbach's Clatsop Tree Farm and last winter, while cruising in the area, company foresters discovered the three stones. They were removed and temporarily stored at the tree farm headquarters near Seaside.

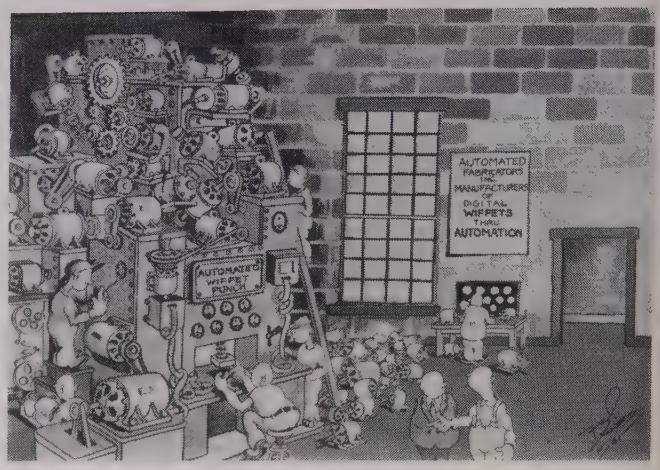
One of the stones was presented to the Clatsop County Historical Museum at Astoria earlier this summer where it is now on permanent display.

U. S. Forest Products Laboratory

Eight New Reports Available

The results of recent research carried on at the U. S. Forest Products Laboratory, Madison, Wis., are contained in eight new reports now available for general distribution.

Report 1769-26, "Can American Elm Be Dried Without Excessive Warping?"



"This proves that automation doesn't cause unemployment." Only the fertile imagination of cartoonist Bill Eddy could dream up such a hodge-podge just to prove that the end result of automation is more jobs. This cartoon is one of 12 poking fun at man and his environment in the 1961 calendar of Minneapolis-Honeywell's Brown Instruments Division. The calendar has —been an industry favorite since it first appeared in 1938 with businessman-inventor-world traveler Eddy, then as now, the artist

Report 2196, "Decay Resistance of Experimental and Commercial Particle Board."
Report 2197, "Importance of Balanced Construction in Plastic-Faced Wood Panels."
Report 2189, "Sulfate and Prehydrolysis-Sulfate Pulps for Nitration. Relation of Pulp Characteristics to Certain Preparation Variables."
Report 1877, "Deflection Characteristics of Two 20-Foot-Diameter Laminated Wood Rings Subjected to Compressive Loading Along a Diameter."
Technical Note No. 263, "FLP Show-Through Comparator for Furniture Panels."
Report 2193, "Significance of Tension Wood in Furniture Cuttings of Red Oak."
Report 2194, "A Method of Indirect Calculation for Use in Log Grade Analyses."

Single copies of these reports may be obtained by writing to the Director, U. S. Forest Products Laboratory, Madison 5, Wis.

Advertising Exhibits

A cross-section report of 101 ideas in exciting new exhibits of products and services to help solve advertising and sales promotion headaches has been issued by the Advertising Trades Institute for its 15th annual Advertising Essentials and National Sales Aids Show, Opening on March 27–29, 1961 at the Hotel Biltmore, N. Y.

OBITUARY

Charles H. Champion

Charles H. "Chuck" Champion, Manager of the Paper Department of R. T. Vanderbilt Co., Inc., died suddenly on Monday, November 7, 1960, of a cerebral hemmorage at Norwalk Hospital, Norwalk, Conn. at the age of 64.

Mr. Champion was well-known throughout the paper industry in the United States and Canada having been with the R. T. Vanderbilt Co., Inc., for 30 years.

He is survived by his widow, Gladys Fisher Campion, and two sisters, Mrs. W. I. Jones of Belmont, Mass., and Mrs. E. C. Noyes of Lexington, Mass.

DIVISIONS AND COMMITTEES

Reports of Activities

Coating and Graphic Arts Division

Graphic Arts Committee

The Graphic Arts Committee met in the Commodore Hotel, New York, at 2:00 p.m. Monday, Feb. 22, 1960. Minutes of the Feb. 23, 1959, meeting were read and approved. The Group Chairman reported on their activities during the preceding year.

James Wing (Papers Committee) reported that five papers had been presented at the Annual Meeting. He reported on the problem of obtaining the papers for the Coating Conference and has stated that papers for the Coating Conference were still needed.

Alex Glassman (Surface Strength Subcommittee) in reporting on Project 130, covering the survey of pick testing instruments, Glassman reported that the work on the project had been suspended and a paper presented showing results obtained during the study at Lehigh University. The problem had not been completely solved and some additional laboratory work was required to settle the problems of agreement between the results from one instrument and between instruments. Further work at this time could not be justified and the project has been concluded at Lehigh. Glassman reported that temperature sensitivity resulted in differences of 50 to 100% between the results from the same instrument and that temperature control of at least ½ degree might be required.

Glassman further reported that on Project 166 work had been started in July after a conference of the subcommittee in Rochester and considerable progress has been made in the correlation between pick testing instruments and press evaluation of papers. It is expected that the I.G.T. print test instrument will become a standard method for pick testing, but that changes in method of inking the rollers will be required. He anticipated a standard method before the end of 1960.

Chairman Morton suggested that a status report on Project 130 be prepared for the TAPPI Office. Dr. Walker, in commenting on the report, stated that the present study is related mainly to paper failure, but that during printing there are other factors to influence print performance. These include wet picking and scattered or isolated or defective spots or lint spots. They are difficult to test with small area testers. The chairman urged that all committee members send comments to Glassman on this latter aspect of picking difficulties.

Fred Oppen (Printability Subcommittee) reported that progress had been made in the development of definitions for printability terms. He had worked with Committees of the Research and Engineering Council of the Graphic Arts and had reached agreements on the terms print quality, printability, and runability. These terms are to be presented to both TAPPI and R & EC Committees for approval. Updated copies of these terms are included with these minutes.

With respect to the preparation of an outline on print testing, the subcommittee distributed the proposed outline to the committee members present, which included an introduction outline of proof press methods and the I.G.T. method of print testing. Chairman Oppen requested comments from the Committee members.

William Walker (Ink Receptivity Subcommittee) reported on Project 168. The subcommittee seeks to establish standard methods for evaluating printing surfaces, and since basic data are limited, a project at Lehigh University is designed to learn about the mechanism of ink transfer and the part played by ink receptivity. The project includes a statistical study in transfer of different inks and the variables, such as speed and pressure during the printing process. Papers and inks are being characterized and ink transferred at different film thicknesses is being studied.

Simmons commented that the Testing Committee is reviewing the wax pick testing methods and suggested that the Glassman subcommittee contact the Testing Committee

M. C. Rogers (Editorial Subcommittee) presented an outline for the monograph to be prepared by the Graphic Arts Committee, Trelfa commented that the Coating Division has been active in the preparation of monographs and that there are two approaches to be taken in the preparation of such publications: (1) the author-chapter and (2) the committee approach.

The outline approach follows generally the committee approach, but the editors to be selected are specialists in the field covered. Certain editorial help at the TAPPI Office will be utilized.

Glassman suggested that the terms used in the monograph to be consistent with those used in the APPA dictionary.

Jacqueline Fetsko (Publicity Subcommittee) reported that abstracts for the 1959 program were sent to several publications and that good coverage was obtained. She commented on the need for committee publicity in view of the fact that TAPPI maintains a public relations office. Chairman Morton stated that the Graphic Arts Committee is unique in that it covers a wide field outside the paper industry proper and that a publicity committee is unnecessary. He appointed L. E. DeLauter chairman of publicity for the ensuing year in view of Miss Fetsko's inability to continue with the work. He is to give publicity to the committee minutes and to the activities of the various Graphic Arts Subcommittees.

George Sears, reporting for Mr. Verseput on Smoothness and Compressability Subcommittee, stated that the nip spreading technique used on five papers and five boards at The Institute of Paper Chemistry, but that response from printers giving experiences with paper and board has not been good.

Project 347 relating to the use of the Proficorder has been inactive as a printability measuring device during the past year.

Considerable discussion took place under the subject of new business for the committee. This was especially true in connection with comments on the application of the proof press as a pick testing device. Because of the ready availability of proof presses, Mr. Glassman suggested that the various proof press methods for pick testing should be published, not as standard methods, but as methods which are being applied to specific problems. It was moved by Glassman, seconded by Oppen, that the Surface Strength Subcommittee survey the paper and printing industry with reference to currently practised picking procedures. The objective is to develop a routine control method for surface strength evaluation. The motion was carried unanimously.

Chairman Morton discussed the surface strength and printability relationships and suggested that the Printability Subcommittee meet with the Pick Testing Subcommittee with a view toward the use of the I.G.T. instrument for both purposes. With respect to the development of plans for routine control methods, Chairman Morton appointed Bruce Redpath as chairman of a subcommittee to consolidate the routine control method data. Chairman Morton requested volunteers to serve on the program and papers committees with Messrs. Wing and DeLauter. W. L. Rhodes volunteered.

In commenting on definitions, Dr. Walker suggested that a definition in the surface strength area need clarification. Glassman was to report at the next Annual Meeting or earlier.

R. T. Trelfa (chairman of the Coating and Graphic Arts Division) announced the reappointment of C. A. Morton as chairman of the Graphic Arts Committee. He commented on the fact that substantial portions of the research grants by TAPPI were results of efforts and activities of the Coating and Graphic Arts Division. There was considerable discussion of publication problems, the committee urging that efforts be made to improve the publication. Trelfa reported that improvements have already been effected.

M. C. Rogers, *Secretary*

Converting and Consuming Division

Plastics Committee

A meeting of the TAPPI Plastics Committee was held at the Syracuse Hotel, Syracuse, N. Y., on Tuesday, Oct. 18, 1960, at 2:00 p.m.

The Chairman, W. N. Stickel, pointed out that the Plastics Committee was growing too large and covered too wide a range of interests and may need to be subdivided.

The current status of the various committee projects was reviewed by the chairman of each as summarized below.

Project No. 784—Resin Identification and Determination. (R. L. Savage, Naugatuck Co., chairman). Mr. Savage and Mr. E. Newell of the Naugatuck Co. reviewed the work carried out by their company on an infrared method developed to analyze resins and polymers in general in paper. A report from them was circulated to members. The method will be extended to some other polymers suggested by the committee and further test samples submitted to Mr. Savage for evaluation and checking with the known polymer contents. It was urged that after this the Naugatuck work be published as soon as possible.

Project No. 586—Properties of Paper Affecting Adhesion of Resins Used in Extrusion Coating. (J. Thornton, F. W. Egan Co., chairman). 94 questionnaries were received concerning the various test methods used for adhesion. There was lively interest in this project and a separate subcommittee would be set up to cover all extended plastic coating problems including the project itself.

Project No. 625—A Fundamental Study of Graft Polymerization of Monomers with Cellulose. (H. Arledter, Mead Corp., chairman). This project has been submitted to the appropriations committee for funds to cover a research proposal for this work and was rejected by a 5-5 vote. It was decided to leave this project in abeyance for the time being.

Project No. 785—Internal Bond Testing. (F. Rosenthal, Knowlton Bros., chairman). The results of the round robin tests of three suggested methods on five papers were reviewed by Dr. Rosenthal and the data analyzed statistically by Mr. Bicking of the Carborundum Co. The direct tensile pull method using the Instron tensile tester appeared to give the best results and more tests would be carried out with The Mead Corp. and National Starch and Chemical Co. cooperating with the three original members (Dixie Cup, Knowlton Bros., and Texon, Inc.).

All the projects would be reviewed again at the February meeting in New York together with other possible future activities of the Plastics Committee.

V. T. Stannett, *Acting Secretary*

Wet Strength and Interfiber Bonding Committee

A meeting of the Wet Strength and Interfiber Bonding Committee was held at the Hotel Syracuse, Syracuse, N. Y., Oct. 18, 1960.

Two new members were welcomed to the committee; Dr. A. C. Schmalz, of Hercules Powder Co., and C. J. Allison, Jr., of American Marietta Co.

Research projects on the retention and curing of wet-strength resins that were sponsored by the committee at The Institute of Paper Chemistry and at Syracuse are essentially completed. In response to suggestions for other projects that this committee might be interested in sponsoring the following were offered:

1. Additional work on the location of wet-strength resins on or in the paper fibers. This would probably involve microscopy and dyeing studies.
2. The retention and effect of polysaccharide wet end additives. The chairman appointed a subcommittee of Cushing (chairman), Schmut, and Hentschel to study and report on the feasibility of such a project.
3. The behavior of wet-strength papers in various non-aqueous solvents.
4. The retention mechanism of simple long chain wet-strength agents such as polyethyleneimine or polypropyleneimine. This might be expanded to include polyamideamine products. (Mr. Britt requested Dr. Sarkanen of Syracuse to submit proposals covering items 3 and 4.)
5. A study of wood extractives (hardwood and/or softwood) in high yield pulps. A subcommittee consisting of Schmut (chairman), Eastes, and Becker will prepare a summary of such work conducted at W. Virginia and elsewhere and if indicated, make one or more proposals for TAPPI support.

It was agreed that there would be no wet-strength sponsored program at the February, 1961, TAPPI meeting but that there would be our usual annual committee meeting.

C. S. Maxwell, *Secretary*

Corrugated Containers Division

Corrugated Containers Steering and Advisory Councils

A joint meeting of the Corrugated Containers Steering and Advisory Councils was held at the Royal York Hotel, Toronto, Oct. 10, 1960.

Chairman Mendlin called the meeting to order at 9:00 a.m.

1. *Minutes of the Previous Meeting* of the Steering and Advisory Councils, Feb. 22, 1960, were accepted as written.
2. *Tenth Corrugated Containers Conference.* R. W. Buttery, general conference chairman, reported that all details appeared under control for the conference. Mr. Buttery received the sincere thanks of the group for the excellent handling and planning of the meeting.
3. *February, 1961, Meeting.* R. C. Hutcheson, general chairman of the February, 1961, meeting, discussed the status. The Industrial and the Engineering Committees are working out the program, each handling a session composed of four speakers. Engineering has two of the four lined up, Industrial Engineering is completely lined up for all four speakers.

The group expressed desire for a third session (which in the past has been an open forum on box plant problems with

Corrugated Containers Conf. Steering & Advisory Council. (Front): H. T. Scordas, Union Bag-Camp Paper Corp., New York, N. Y.; J. J. Koenig, Crown Zellerbach Corp., St. Louis, Mo.; B. Mendlin, Cornell Paperboard Products Co., Milwaukee, Wis.; R. W. Buttery, Bathurst Containers Ltd., Montreal, Que.; K. Provo, Crown Zellerbach Corp., St. Louis, Mo. (Back): P. J. Cox, Con. Water Power & Paper Co., Wisconsin Rapids, Wis.; R. C. Hutcheson, Union Bag-Camp Paper Corp., Spartanburg, S. C.; R. D. Merrill, Stone Container Corp., Chicago, Ill.; R. L. Jenk, Mead Containers, Inc., Dayton, Ohio; T. W. Carroll, Owens-Illinois Glass Co., Toledo, Ohio; H. W. Seibel, Crown Zellerbach Corp., St. Louis, Mo.; H. O. Teeple, TAPPI, New York, N. Y.

questions and answers by a panel of experts). H. O. Teeple mentioned that it may be desirable to have the third session consist of lists of questions on corrugated containers in general with a speaker who would discuss these questions and lead the question and answer session. Burt Mendlin suggested that The Institute of Paper Chemistry film on corrugating be shown followed by a question and answer session with Bob McKee present. Messrs. Hutcheson and Carrol said they would get together and work out details at their committee meetings.

4. *Committee Reports on 1961 Plans*

Production. Chairman Buttery stated that four projects are under consideration. The committee now has about 18 members. New members are showing great interest. H. O. Teeple suggested that a status report on the University of Manitoba project be issued before the end of this year, inasmuch as TAPPI is furnishing funds.

Process and Quality Control. Chairman Seibel reported this committee in good order with 24 members working four projects. The Defect and Remedy Manual has progressed to where it appears possible to have a complete draft by February to offer for publication. The other three projects are developing (Statistical Methods, Pin Adhesion, Quality Control Questionnaire). This committee has responsibility for the technical program for the twelfth. Corrugated Containers Conference at Boston, and this is also being worked on.

Industrial Engineering. Chairman Carroll, reported 17 members now on this committee, and that they have been working on the program for the 1961 February meeting in cooperation with the Engineering Committee.

Raw Materials. Chairman Wilmer reported progress with more to report after his subcommittee meeting. The Adhesive Subcommittee has been working on a "Manual on Corrugating Adhesives." Other instruction manuals are being considered.

Engineering. Chairman, Hutcheson reported that the Engineering Committee now has 21 members. One of their projects is "Box Plant Design," which, it is anticipated, will result in a booklet on the subject. It was mentioned that the Engineering Committee has been holding some high-type meetings of great value to the participants.

Eleventh Corrugated Containers Conference, San Francisco, Sept. 11–13, 1961. H. W. Wilson, general conference chairman, reported that he, O. P. Wanamaker, technical program chairman, and H. O. Teeple met in San Francisco. At present, local arrangement details and the technical program are to be crystallized. The Production and the Engineering Committees had been delegated to assist Mr. Wanamaker in the preparation of the technical program. Mr. Hutcheson (chairman, Engineering) reported that Messrs. R. W. Catzen and D. C. Kaley have been named moderators. A meeting of the various individuals involved was to take place during the Toronto meeting with Mr. Wanamaker and all the other individuals assisting to have as the objective the complete wrapping up of all the details of the Fall 1961 meeting at San Francisco—themes, speakers, etc.

Plans for February 1962 Meeting. Responsibility for developing and executing the February, 1962, meeting had been placed with the Industrial Engineering Committee and the Production Committee. T. W. Carroll accepted the position of technical program chairman for this meeting.

Twelfth Corrugated Containers Conference, Boston, Oct. 23–26, 1962. The Process and Quality Control and the Raw Materials Committee are responsible for the technical program. P. E. Cox was asked to be general chairman, with H. E. Dunholter to be contacted to accept technical program chairmanship. The Statler-Hilton has been booked for this occasion.

Thirteenth Corrugated Containers Conference, Detroit, Oct. 22–25, 1963, Statler-Hilton. The general conference chairman of the Detroit meeting and the technical program chairman will be announced later.

1964, 1965, 1966 Fall Corrugated Containers Conferences. In order to avoid running into situations (such as in San Francisco) where it was necessary to accept an early date for a meeting because the most desirable dates in the best hotels are already filled by other meetings, it was suggested that locations and reservations be made now for our fall Corrugated Containers Conferences for 1964, 1965, and 1966. It was unanimously agreed that plans would be to conduct the meetings as follows in the second or third week of October:

1964: Dallas
1965: Atlanta
1966: Los Angeles

H. O. Teeple (TAPPI Staff) will immediately begin to line up the best facilities on the above basis on dates that will not conflict with other industry meetings. He will report the outcome soon as possible.

Election of Officers of the TAPPI Corrugated Containers Division (1 year). The Nominating Committee composed of L. K. Burnett, F. D. Long, and R. L. Jenk, recommended the following slate of Division officers for the forthcoming year.

Chairman: J. J. Koenig
Vice-Chairman: R. W. Buttery
Secretary: K. R. Martin

No other nominations were received, and the foregoing were elected, subject to the approval of the president of TAPPI.

Proposed New Committee. R. L. Jenk proposed that a new committee be considered, to be called "New Product and End Use" Committee or something similar. This would be intended to fill a need for a committee to cover the technical applications of corrugated board, etc.

Mr. Jenk was asked to have a report on this at the February meeting, and he was requested to gel the thinking with a memo to all members of the SAC before the meeting.

Respecting the Various Committees. Because of the important and interesting subjects that develop in the meetings of the committees, it was agreed that the Division Steering Committee should be added to the mailing list of all committee meetings. Therefore, the various committees are asked to give some detail to their minutes, particularly on items and ideas which could be regarded as of possible interest to others.

Other suggestions were made, based on experiences of some of the committees, which may be helpful to all, such as the following.

Bull sessions, prior to the actual meeting, have been found helpful in stimulating discussion of subjects not on the agenda, but which should be covered at the meeting.

The Pittsburgh Airport continues to be a desirable and most convenient spot for committee meetings. The facilities right at the airport hotel are excellent, making it possible to fly in, stay at the airport, have a full-day meeting and fly out the same day. H. O. Teeple will assist any committee in reserving facilities in advance.

Submission of Papers Prior to Deadlines. All members were advised that the proper submission of papers as early as possible and *not later than the deadlines* set by TAPPI continues to be a major problem, not only as far as the planning of the programs is concerned, but especially when preprinting of papers in advance of the meeting is required. Unless papers are in by the deadline time, it is impossible to include them in the preprint. Tardy papers thus lose the favorable publicity and advance interest for which preprinting is done. All concerned in advising, obtaining, and contacting speakers are urged to continually stress the importance of submitting manuscripts strictly according to instructions and positively not later than the deadline.

It is suggested that the technical program chairman in all cases take complete charge, appoint the moderators and all ride herd on early submission of papers by their speakers. Besides making for smooth running and preprinting, early submission of papers gives moderators and the technical program chairman time to check over and constructively criticize the papers to finally present the highest quality technical program possible.

Miscellaneous.

H. O. Teeple advised that the manual "Planning a Conference" is being rewritten and will be issued soon.

The printing workshop film produced by the Raw Materials Committee under direction of Ron Wilmer will be made available on loan to responsible TAPPI members or Corporate Members by means of four prints made for the purpose. Anyone wanting to borrow the film should contact Mr. H. O. Teeple at TAPPI Headquarters *in writing.* Should a company want to buy a reprint of the film (approximately $200), TAPPI will arrange. The matter of service charge will be looked into by Ron and Herb. Details will be developed further, but the basic principle will be to have each plant that wants to borrow or buy the film write H. O. Teeple and commit themselves individually in the responsibilities involved.

The entire group expressed sincere appreciation to Mr. Wilmer and his company for making the film available, and Chairman Mendlin was directed to send a letter of appreciation to them.

G. K. Provo offered a suggestion that the Engineering Committee consider the development of an "Operating and Maintenance Manual" to provide information helpful to management.

J. J. Koenig (substituting for W. P. Blamire, *Secretary*)

Corrugated Containers Engineering Committee

The meeting was called to order at 2:10 p.m. Oct. 10, 1960, at the Royal York Hotel in Toronto by Chairman Hutcheson.

The minutes of the Pittsburgh meeting were approved as submitted. Motion by Knecht, seconded by Ellinger.

Chairman Hutcheson welcomed W. F. Ward as a new member of the Engineering Committee.

Progress Report Project No. 776. Westfall reported that nothing new could be added to the takeup ratio project at this time. He indicated that Moser will work with Haire on this important project as soon as Continental Can receives delivery on new instruments at their Philadelphia plant.

Corrugated Containers Engineering Committee. R. C. Hutcheson, chairman, Union Bag-Camp Paper Corp., Spartanburg, S. C.; A. Richardson, vice-chairman, Crown Zellerbach Corp., St. Louis, Mo.; R. C. Berger, secretary General Electric Co., Schenectady, N. Y.

Moser again reviewed the objectives of this project by noting that takeup ratio depends not only on flute contours but also the condition and quality of the corrugating medium, width, temperature, speed, and sheet tension. Three different test setups will soon be in operation. They are:

Lanzit Corrugated Box Co.—Westfall
Owens-Illinois Glass Co.—Newton
Continental Can Co.—Haire & Moser

Mr. Westfall's committee expects to accumulate meaningful data on all three of these installations between now and February, 1961. It is expected that these data will reveal how takeup ratio is affected by all of these many variables. Hutcheson asked that the subcommittee be prepared to present their findings at the next meeting of this committee on Feb. 21, 1961, in New York City.

Flexographic Printing with Glu-Lok Machine. H. F. Thorn presented a short paper on the Hooper-Swift Glu-Lok machine. Mr. Thorn then displayed several typical examples of flexographic printing on corrugated container board.

Box Plant Design Project.

1. Mr. Westfall reviewed with the committee his write-up on product mix and volume. After considerable discussion it was decided to modify the size specification such that it might be expanded from 1300 to 2500 tons per month. This is to be based on 64 tons per million sq. ft. The volume of slit scoring was changed from 3% to 1% of total square footage.
2. Mr. Davies presented his paper on plant site, location, and shipping facilities. It was felt that perhaps it might be well to add some unidentified case histories that would serve to further illustrate some of the problems associated with the selection of a suitable plant site.
3. Time did not permit the presentation of Mr. Nitchie's report on machinery selection and drives; however, he did distribute a written summary for review by the committee prior to the New York meeting in February.

High-Speed Motion Picture. Through the courtesy of The Institute of Paper Chemistry, Mr. Richardson arranged for a showing of a motion picture which illustrated in slow motion the progress of a sheet of medium through the corrugating rolls, the glue applicator, and the combiner with the liner. This was received with great interest and Chairman Hutcheson expressed the thanks of the committee for Mr. Richardson's contribution.

Size of the Committee. After considerable discussion, Mr. Richardson moved that the size of the Engineering Committee be limited to 30 members; that each be an engineer; and that the basic equipment manufacturers be limited to 12

members. No more than one voting member will be permitted from any one company. Motion was seconded by Mr. Goettsch. Motion carried.

New Members. After considerable discussion, the following new members were elected to serve on the Engineering Committee:

J. M. Bentley—Westinghouse Electric Corp.
Philip Ziegler—St. Joe Paper Co.

The secretary was instructed to prepare letters of welcome to these new members.

Steering Council Meeting Report

1. The technical program for the New York meeting in February, 1961, will be shared by the Engineering and the Industrial Engineering Committees. R. C. Hutcheson has been appointed the General Chairman.

At the moment two papers have been definitely committed from the Engineering Committee. These are

"An Evaluation of the Hooper Knife," by L. J. Grogan, Maxwell Bros. Inc.
"The Performance of 39-C Flute Rolls," by T. B. Haire, Continental Can Co.

Mr. Goettsch indicated that he expected to be in a position to announce a definite speaker to cover the proposed subject, "An Evaluation of the Langston Knife" within the next few days.

2. The technical program for the fall meeting in San Francisco will be equally shared by the Engineering and Production Committees. The chairmen of these two committees will act as co-chairmen of the technical program. H. O. Teeple and his associates will be responsible for all of the mechanical details in connection with the fall meetings from now on. The new procedure will operate just as the New York meetings have been handled in the past.

Future Committee Meetings.

1. In the future it was suggested that the fall committee meeting be a full day with the vice-chairman handling the morning session while the chairman is attending the Steering Council meeting.

2. It was also suggested that the February meeting be extended to a full day with the Monday afternoon session under the vice-chairman and the Tuesday morning session under the chairman for the same reason.

3. Finally, it was suggested that the May meeting be moved from Pittsburgh to another location in the vicinity of a new box plant operation. It was further suggested that the meeting be extended from one to two days, thereby affording the opportunity to include an inspection trip. Decisions on a specific location for the 1961 May meeting were deferred until the February meeting in New York.

Corrugated Containers Industrial Engineering Committee

Chairman Carroll opened the meeting held Oct. 10, 1960, at the Royal York Hotel in Toronto by reviewing the Steering Committee meeting of the morning. The group proceeded to discuss plans for the spring TAPPI meeting and the half-day session which the Industrial Engineering Committee will conduct. Mr. Carroll was elected chairman of the session.

The theme of the session is to be the use of industrial engineering services by line organizations. H. A. Buckley will introduce this theme in the first talk. A draft of this talk was read to the group by Mr. Buckley and all members agreed that his proposed talk was excellent.

Arrangements for speakers and subjects were as follows:

1.	Methods	J. C. Spraque
2.	Production reporting	C. Craigo
3.	Work measurement	F. H. Cloud
4.	Waste control	R. J. Buckley
5.	Equipment replacement	F. Came
6.	Basic I. E. policy	E. Rhode
7.	Supervisory training	R. S. Owen

Corrugated Containers. Production Committee R. W. Buttery, chairman, Bathurst Containers, Ltd., Montreal, Que.; D. Blackburn, vice-chairman, Martin Paper Products, Ltd., St. Boniface, Man.; L. F. Ashwood, secretary Downing Box Co., Milwaukee, Wis.

Mr. Carroll will coordinate the assembly of the session and all speakers should submit their material so that Mr. Carroll can meet the following TAPPI requirements:

Date	*Requirement*	*No. copies*
Dec. 1, 1960	100- to 200-word abstract of talk	4
	Brief biographic sketch	4
Jan. 1, 1961	Completed manuscript	4

In addition, Mr. Carroll would like another eight copies (total of 12 copies each) to furnish each speaker with a complete text of the session.

The possibility of an Industrial Engineering TAPPI project was discussed by the group. It was decided that Mr. Owen would make a preliminary investigation on the feasability of producing a time study rating film for use of the industry. Mr. Kline volunteered some films that Container Corp. has developed for that purpose.

It was observed that other TAPPI groups have an informal meeting of their members in addition to the formal committee meeting. The group felt that there was much industrial engineering knowledge in the room and that an informal exchange would be valuable. Plans will be made before the next meeting for an informal gathering of the committee members.

F. H. Cloud

Corrugated Containers Process and Quality Control Committee

The meeting was called to order at 2:40 p.m. on Oct. 10, 1960, at the Royal York Hotel in Toronto, Ont., by Chairman Seibel.

The meeting commenced with a status report on Project No. 752, "A Survey of Plant Quality Control Methods," by Project Chairman Ned Varner. There was no new progress reported. In fact Mr. Varner reported that the records of previous work on this project under Harvey Stallsmith had been misplaced or had not reached him. It was resolved that he would get this previous work together and create a committee to report on this at the February meeting.

Harry Dunholter, chairman of Project No. 762, "Defect and Remedy Manual," reported that he, Henry Seibel, and Alan Swartz had met in New York on Sept. 14, 1960, to coordinate all committee work for presentation at this meeting. The following recommendations of this committee were presented to and received the approval of the committee members present.

1. Make the manual in loose-leaf form on $8^1/_2$ by 11-in. paper so it can be added to or revised easily.
2. The format should be one defect per page defined at the top of the page with a photo beneath, below the photo there

Corrugated Containers Process Quality Control Committee. H. W. Seibel, chairman, Crown Zellerbach Corp., St. Louis, Mo.; H. Dunholter, vice-chairman, Eastern Box Co., Baltimore, Md.; S. L. Goodrich, secretary, General Box Co., Des Plaines, Ill.

would be two columns, one on the left headed "Causes" and one on the right headed "Remedies."

3. Terminology should be standardized using the most common terms for defect and equipment.
4. Target date for manual publication, mid 1961.

It was also reported by Mr. Dunholter that many good defect photos are in his possession but more are needed. Mr. Seibel replied that funds could be obtained from TAPPI Headquarters for financing these needed photos. Ned Varner, and S. Rubinstein offered additional photographs of defects. It was requested that all project committee members resubmit the defect remedy information in the form accepted by the whole committee to Harry Dunholter no later than Dec. 1, 1960. This is so a tentative manual can be assembled and in the hands of committee members prior to the February, 1961, meeting.

Harry Dunholter thanked the following project committee members for their help: J. Corcoran, G. Leoky, K. Martin, Alan Swartz, H. Seibel, Ned Varner, and S. L. Goodrich.

Henry Nelson, chairman of Project No. 754, "Manual of Simple Statistical Techniques," stated that he had no new progress to report. He than asked to be relieved of the chairmanship of this committee due to the pressure of business, but that he would gladly remain as a committee member. Mr. Rubinstein was asked to accept this chairmanship and to draw assistance from the following committee members in addition to Mr. Nelson: Mr. Timmer, Mr. Corcoran, and Mr. Siddiqui. Mr. Rubinstein asked to have time to consider his decision and that he would reply in two weeks. Further discussion on this project was then deferred to the next meeting.

Frank Albert, chairman of Project No. 761, "Evaluation of the Pin Adhesion Test," passed out the consolidated results of the questionnaire and discussed them with the committee. H. Seibel stated that these data should be of value to the raw materials subcommittee on adhesives in an upcoming evaluation of adhesives consumption and pin adhesion. It was decided to try and obtain the pin adhesion results from a special pin adhesion test comparison that is proposed by an industry laboratory, in order to supplement our present data, all in light of making a routine pin adhesion test method. Due to this proposed test, it was decided to postpone additional remarks on this project to the next meeting.

Chairman Seibel closed the discussion of old business by stating that the steering council requested minutes of all committee meetings be sent to them so no duplication of committee work would result.

The discussion of new business revolved around proposed project topics. The following subjects were suggested.

1. Setting up effective quality control program for an average size box plant. (Information on this item passed out in form of a reprint of a speech by Mr. Rubinstein, entitled "Quality Control.")
2. Correlate column compression to box compression. (Mr. Nelson discussed the new G.E. test and comparison to F. P. L. data.)
3. Comparison of Concora results to convertability suggested by Mr. Ostrowski.

Chairman Seibel stated that due to the large amount of work yet to do on present topics, time could be best spent on bringing these to completion, but he instructed the committee to keep these and any new topics in mind for deferred discussion at the next meeting.

STANLEY L. GOODRICH

Corrugated Containers Production Committee

The Corrugated Containers Production Committee met Oct. 10, 1960, at the Royal York Hotel, Toronto, Ont., at 9:00 a.m. to 12:00 noon.

Project No. 695—Adhesive Factors. In that Mr. Blackburn has left the industry, Mr. Buttery will assume this responsibility and confer with Professor Germain in Winnepeg this November. The study is intended to determine if any relationship exists between adhesive consumption and flutes. No attempt was made to ascertain what is good consumption. Because the report is somewhat vague, until Mr. Buttery can confer with Professor Germain, it is difficult to interpret the findings; so these will be available for the February Meeting.

Mr. Mendlin observed that the total of the single-face and the double-face figures for each flute individually was slightly over 2.5 in all instances which made it questionable that the modification factors used for the different flutes by different companies were accurate. Mr. Wilson explained that the tip radii vary with the different flutes so that for all the consumption should be the same. Mr. Mendlin suggested that the represented companies use the Germain factor on current production and see if the usage curve is more consistent than with the factors each has been using.

Project No. 785—Supervisory Training. Mr. Ashwood distributed lesson plans on safety, waste, costs, and company policy to supplement those previously issued. Lesson plans on union contract, errors, and quality control should be ready within the next few months. In addition to the subcommittee, several other committee members participated by preparing plans (Messrs. Simpson and Adams—safety, Catzen—company policy, Kaley—waste, Jordan—costs, Provo—quality control, Hurrell—errors, Johnson—union contract. Mr. Provo questioned, since the Quality Control Committee was working on a booklet of defects, if this should replace the contemplated lesson plan. From discussion, the committee felt that the Quality Control Committee work could possibly be used as a text but that the lesson plan should be completed. It was requested that anyone who makes use of these lessons should suggest any changes that might be beneficial to the subcommittee before this project is completed and presented for publication.

Project No. 781—Errors. Mr. Hurrell summarized the results of a questionnaire circulated to 11 plants. Most appreciate the importance of determining sources of errors but few do much investigating. Most record the cost of errors. Two thirds of errors are found after the boxes leave production. Sixty per cent of the companies hold both production and specifications responsible if a specification error should have been caught by production. Most companies take disciplinary action against individuals responsible for errors. Eight per cent of the errors occur in production Control, while 23% in corrugating. A large portion of errors in any operation occurs because of misinterpretation of instructions or specifications (40% in printing and 47% in shipping are due to this cause). Some companies file

Corrugated Containers Industrial Engineering Committee. T. W. Carroll, chairman, Owens-Illinois Glass Co., Toledo, Ohio; R. S. Owen, Vice-Chairman, R. S. Owen & Co., Chicago, Ill.; F. H. Cloud, secretary, Packaging Corp. of America, Chicago, Ill.

error information with each employee's record yet have a limitation of 12 months for any disciplinary action on any individual errors.

Before circulating the same questionnaire to additional companies, discussion occurred on the objective of this project. It was felt that the project would be of value if it helps members reduce both the number and cost of errors. To date the investigation is of value in that it shows where the bulk of errors occurs. It was felt that the study should continue to determine the seriousness of errors and the relative cost among companies. A yardstick to measure errors should also be developed such as: dollar value, number of error dollars relative to sales dollars, number of errors, or number of errors relative to number of orders. At the conclusion of the project, the information might be circulated to the industry or the data could be used for preparing a technical paper. Messrs. Comly (Connelly Containers) and Glass (Green Bay Box) were added to this committee.

Project No. 791—Production Reports. Mr. Provo reported that he had received and reviewed various production reports obtained from member plants. There was such a wide variation of information that it appears extremely difficult to measure performance between plants. It was the consensus of opinion that no attempt should be made to use such reports to compare plants but rather to provide production managers with relatively simple figures so that they might keep their fingers on what is going on without spending hours wading through reports.

It was pointed out that efficiency by centers and by the total operation is the only true measure *if* production standards are correct. The standard hour system used by some companies requires at least one industrial engineer in each plant to maintain.

It was decided that Mr. Provo will submit a questionnaire to each of the member plants to compile the necessary figures for the corrugator for October and November to determine how practical it might be to develop a yardstick for this one operation. Those plants having more than one corrugator should select the best machine for this test.

New Projects. A study on waste and what is done to motivate personnel to reduce it by presenting rewards, etc. and how successful these are was considered would be most helpful. Because F. B. A. keeps waste statistics, there is no need to duplicate that; however one company that is doing an outstanding job might present a paper on this subject. Another thought was to have a special meeting devoted to the different members discussing what they are doing and with what results. No action was taken.

Another problem facing the industry is controlling matched sets. This would include study of shortages and overruns on multi-item orders and what is being done about these. Mr. Dowd was appointed chairman.

The problem of accurate counting in the various operations was discussed. No action was taken on a project.

Membership. This meeting was the best attended of any of the committee to date. Future program planning will be directed toward involving each member in some projects.

September, 1961, Meeting. The Production Committee will be responsible for this with Mr. Wilson as general chairman and Messrs. Kaley and Katzen as moderators for the technical sessions in San Francisco.

LOREN F. ASHWOOD, *Secretary*

Pulp Manufacture Division

Alkaline Pulping Committee

D. Wetherhorn Continental Can Co., Port Wentworth, Ga., committee chairman, opened the meeting of the Alkaline Pulping Committee at the Multanomah Hotel, Portland Ore., 2:00 p. m., Sunday, Aug. 21, 1960, in the Junior Ballroom. Minutes of the February meeting were considered. They were accepted as reported on a motion by T. T. Collins.

No business was taken up as a result of the perusal of the February minutes.

Mr. Wickett chariman of local arrangements summarized the morning meeting of his committee, and pointed out changes in the printed program.

Mr. West, technical program chairman for the conference, reported on the program and the plans for members of the program.

Mr. Teeple covered the registration fee and other details of the meeting.

Mr. Wetherhorn commented on the very fine program for the meeting. He heartily commended the committees and thanked them for their efforts.

The meeting in February was discussed. Mr. Collins volunteered as program chairman and was confirmed as program chairman. As in the past, the committee will meet at 2:00 at the Commodore. Some discussion of papers for the meeting followed. It was decided papers would be closely screened and four good, appropriate papers obtained for the program. A half-day program will be held.

The fifteenth annual meeting set for the Rice Hotel, Nov. 1–3, 1961, was briefly discussed.

J. D. Parrott, Champion Paper and Fibre Co., Pasadena, Tex., was appointed chairman of local arrangements and Mr. Collins, American Box Board Div., Packaging Corp. of America, Filer City, Mich., program chairman.

Ideas for the sixteenth meeting were covered. It was set for Savannah, Ga., the first week in November, 1962.

D. C. Gillespie's, Dorr-Oliver, Inc., Stamford, Conn., resignation from the committee was regretfully accepted. In accepting the resignation, Dave Wetherhorn and the group thanked Dan for his very active participation in the work of the committee.

I. W. Johnson of Dorr-Oliver was recommended for appointment to the committee. On motion by A. W. Pesch, seconded by W. B. Stengle, Mr. Wetherhorn was given a unanimous suggestion for appointment of Mr. Johnson.

A discussion of the progress on the monograph on chemical recovery followed. Dan Gillespie, who has been chairman of this subcommittee, brought the matter up to date. At the moment, the subcommittee is waiting on Dr. Whitney's outline and plan for preparing the monograph. The committee went on record as follows: The Alkaline Pulping Committee stands ready to back Dr. Whitney in his efforts by lending all assistance it can. Mr. Wetherhorn to advise Dr. Whitney of the committees availability. Dan indicated that in accepting the job, Dr. Whitney stated that he was not able to give immediate attention to the project, and work would start this fall. A report is expected for the February meeting.

R. B. Kessler reported for the testing methods subcommittee. The revision of the method of Analysis of Green and White Liquor has been made. It has been reclassified as tentative standard No. 843 and is being processed.

P 26 = 25 Analysis of Black Liquor has been forwarded by Mr. Wetherhorn without number. The membership is now being polled on this method.

Project No. 844—Residual activity test method is ready for submission to the routine control methods committee.

Work will be resumed on the analysis of black liquor in a new attempt to obtain support on the method of solids determination including a definition of solids. It is expected this matter will be ready by the February meeting. Any thoughts on this project should be sent to Mr. Kessler in the interim.

Project on Sulfate Cook and Digester Corrosion. Peter Borlew reported for the committee. This committee is presently following the literature and waiting the opportune time to resubmit its project on this problem. Mr. Borlew suggests the committee members read the article in the June issue of *Tappi* on sulfite reactions.

Project 845—Nonconventional Cooking Methods Committee. E. F. Thode reported for the committee. This project cannot be well defined, but it does not fit the present jurisdictional classifications now in use. It is difficult to prepare a balanced report on this problem. In general, the committee expects the matter to fall in the three following classes:

1. Good idea, but not enough development work to prove its feasibility.
2. Good processes now commerical or commercially feasible.
3. Good processes not now commerically feasible from an economic, materials of equipment, or other reason. Ed asked for the appointment of H. C. Crandall of Mosinee and N. E. Thompson of the Institute as the other members of the committee. Mr. Wetherhorn to make the appointment. The committee hopes to make its first formal report at the February meeting.

H. Y. Charbonnier brought up the matter of a place for the 1963 meeting. The following cities were suggested:

Mobile, Ala.
Greenbay, Wis.
Montreal, Que.
Meridian, Miss.
Flagstaff (Phoenix), Ariz.

Mr. Teeple is to check on hotel facilities and to report at the February meeting. The meeting preferred days of the week were Wednesday, Thursday, and Friday.

R. R. Fuller

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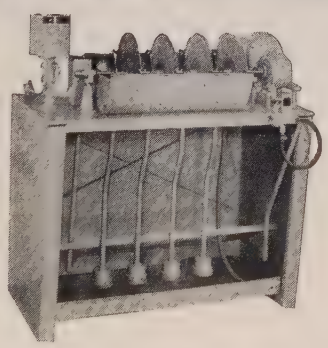

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Engineering or technical graduate with broad experience in pulp and paper industry to collect and edit useful engineering and technical information for distribution to TAPPI members. Age of 35 or over preferred. Project will require 2–3 years. Salary commensurate with qualifications. Proximity to New York City desirable but not required.

Please send résumé of experience, education and salary requirements to:

Executive Secretary
Technical Association of the Pulp and Paper Industry
360 Lexington Ave.
New York 17, N. Y.

(P1046-60)

SALES REPRESENTATIVE
Wanted

Starch manufacturer needs sales representative to call on paper mills in eastern United States. The man we need must have thorough knowledge of the paper industry and a proven sales record. A chemical background is desirable but not necessary. Applicants should have strong managerial capabilities since this job can lead to that of a department manager.

We offer a good starting salary, company car, all expenses paid, and an outstanding pension and insurance program.

Write **Tappi,** P1053-61 giving complete résumé.

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Immediate position open in Research and Development Department of absorbent specialty mill located in midwest. Prefer man with degree of chemistry and three years of paper mill experience. Knowledge of saturating papers and saturating resins desirable.

Write to **P1054-61, Tappi, 360 Lexington Ave., New York 17, N. Y.**

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Well established growth firm offers excellent management opportunity in its expanding research organization. Candidate should possess advanced degree and be well versed in cellulose chemistry with some practical background in paper manufacturing. Experience in specialty industrial papers desirable.

Send résumé and salary requirements to **P1055-61, Tappi, 360 Lexington Ave., New York 17, N. Y.**

Local Section Staff Man

The Association headquarters office has an opening for a young man interested in providing staff liaison for TAPPI local sections and districts. New York City location. Moderate travel involved. Technical education and paper industry experience highly desirable. Interested applicants please send résumés and salary requirements to:

Executive Secretary
Technical Association of the Pulp and Paper Industry
360 Lexington Avenue
New York 17, N. Y.

(P1056-61)

PROCESS ENGINEER
For Integrated Kraft Pulp and Paper Mill

This is an operating job, primarily in the pulp mill, but will include paper mill work.

The man we seek should have from 2 to 5 or more years of sulphate pulp mill experience. He also should have a B.S. or better in chemical engineering, or in pulp and paper technology.

Mosinee is a congenial community of 2000 located in central Wisconsin, far away from the problems of big-city living. Here commuting takes mere minutes. Good school and church facilities. Active social life. Excellent recreation close by: swimming, skiing, boating, fishing, hunting.

The salary is open, dependent upon experience and ability. Replies will be acknowledged and kept confidential.

If you are this man, we will be glad to hear from you. If you are not this man, perhaps you know of one who fits the description. Please call his attention to this advertisement.

Address replies to:

Manager of Manufacturing
MOSINEE PAPER MILLS COMPANY
Mosinee, Wisconsin

(P1057-61)

WANTED

Chief Engineer, with Mechanical or Electrical Engineering Degree, to take full charge of all mechanical and electrical maintenance, power and plant engineering departments.

Must have strong organizational and leadership ability. Experience in Paper Mill maintenance, power and engineering required.

Mill located about ten miles northwest of Center Philadelphia in Montgomery County, Pennsylvania, in an area with a wide choice of desirable living conditions.

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Mr. Paul R. Dugan,
Personnel Director
Hamilton Paper Company
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(P1058-61)

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BS degree, preferably in the paper field, and experience in pulp and paper production,production control, sales, technical service, marketing or research and development experience in the pulp and paper field. Starting salary is dependent upon experience. Superior leave, retirement, insurance and other fringe benefits associated with permanent Civil Service appointment. Send inquiries or complete resume to:

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(P1059-61)

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These opportunities are *immediate,* but we'd like to get acquainted *now* even though you may be currently engaged in projects restricting your availability.

Send complete resume with salary requirements in confidence to:

P1060-61, *Tappi,* 360 Lexington Ave., New York 17, N. Y.

. . . WANTED . . .

For a well known, independent manufacturer and converter of heavy paperboard products, mostly laminated, and subsidiary chemical operations a broad gauge, profit-minded chemical engineer or chemist strong in R.&D. coordination and administration

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Client mill, an honored name in the laminated wood fibre panel field for decades and more recently a coming factor in specialty chemical products, has reached the point in its carefully thought out program of basic research, product improvement and corporate diverisifcation where the Board of Directors feel it essential to centralize the control of all technical activities. Accordingly, a new staff position is being created, as above captioned.

Needed here is what we call a practical scientist—a profit-minded, sales conscious technical executive who can and will work hand-in-glove with top management and other department heads and see to it that the company gets the maximum return from its not inconsiderable technical budget.

Man selected will be directly responsible to the President and will carry the full authority of the chief executive office in every move he makes. If, as and when he proves to the top executive structure—this could happen in less than two years—that he is entitled to take his place at a policy making level, he will be named Vice President of Research and Development.

Make confidential written inquiry in duplicate to Mr. George M. Sunday personally, enclosing two pictures and two copies of comprehensive resume covering vital statistics, education, technical affiliations and chronological treatment of business background and experience, including present and past earnings. Telephone conference will follow, at which time cogent details will be revealed and arrangements made for subsequent personal interview at client's expense.

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(P1061-61)

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PHOTO TEST SUPERVISOR

B.S. in chemistry, chemical engineering, or physics, with 1 to 5 years' industrial experience to assume supervision of in-process photographic testing in release of material based on specifications. Will also conduct test program for product assurance.

Kindly send resume and salary requirements to:

Robert Lamalie
Industrial Relations Division
HALOID XEROX INC.
P.O. Box 1540 Rochester 3, New York

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(P1062-61)

ENGINEERING DIVISION

Questions and Answers

Good engineering questions are solicited as well as answers or alternate answers to the published questions. Material should be sent to TAPPI Headquarters, marked for the attention of H. O. Teeple. The items contributed will be forwarded to the Question and Answer Committee for processing. If comments are to be contributed, please refer to the question number.

*(1-1/61) *Question* (Vibration of a Turbine Set Caused by Loose Joint in Generator Field): **A turbo-alternator set has run satisfactorily for several years. We recently reconnected the fields to operate on 125-v. exciting current, instead of 250 as formerly and lately have carried a heavy overload with low power factor, when vibration spells have developed. This is in the generator only. We cannot find any ground or other indications of electrical trouble, and the rotating field is aligned centrally with the armature. The set will run for hours perfectly when the generator is not in use, but vibration develops soon after load is applied. What causes the vibration?**

*(1.1-1/61) *Answer:* The trouble appears to be due to a loose joint or terminal of one of the generator field coils, which under certain circumstances forms a make-and-break contact, causing a variable magnetic pull in one coil. Probably a terminal or joint was not soldered properly and the excessive field current carried on account of overload and low power factor caused a connection to give way. It sometimes happens that terminals become loose in this manner and are difficult to detect, since the trouble may occur only at certain load conditions when heating is sufficient to destroy proper mechanical contact. It may be possible to locate such a joint by exciting the field and taking the drop of potential across each joint with a multivoltmeter. The bad joint will show an excessively large voltage drop when compared to the others.

*(2-1/61) *Question* (Chord Factor): **What is the cord factor of a coil in an induction-motor winding?**

*(2.1-1/61) *Answer:* The chord factor of any coil in an electrical machine generating an electromotive force is a factor representing the effectiveness of the coil in generating voltage. The cord factor is equal to the sine of one half of the angle in electrical degrees which the coil spans. In a stator core having 72 slots wound for 6 poles, for the coils to span full pitch they would have to span $72 \div 6 = 12$ slots, that is the sides of a coil would have to lie in slots 1 and 13. This would represent 180 electrical degrees and the sine of one half of 180° is 1, hence, the chord factor of the coil is 1, and the coil is 100% effective in generating a counter-electromotive force. Each slot equals $180 \div 12 = 15$ electrical degrees. Then if the coil lay in slots 1 and 11 it would span only 10 slots or $15 \times 10 = 150$ electrical degrees, and the chord factor would be the sine of one half of 150° or 75°, equals 0.96. This means that the winding is only 96% as effective in generating a counter-electromotive force in the latter case as it was in the former. If with full pitch, under a given condition, the winding was good for operation on 500 v., then with the coils in slots 1 and 11 the winding would be good for only $500 \times 0.96 = 480$ v.

*(3-1/61) *Question* (Shutting Down Steam Turbine): **In shutting down a steam turbine, is it advisable to throttle by hand before or after taking off the load?**

*(3.1-1/61) *Answer:* It is advisable to throttle down as the load is taken off. Then, if the main valve leaks, overspeeding will be prevented. This is the usual custom with large units. When the governing mechanism is in good order, this may not be necessary and on small turbines with tight valves, closing the hand throttle is often delayed until the load is removed. Shutting down affords a good opportunity for tripping the emergency valve by hand to determine whether overspeeding occurs at no load, and to test the emergency, after which the throttle can be closed right.

Unanswered Questions

(4-1/61) *Question:* **In paper mill distribution systems where directional ground relays are used as back-up protection, should the instantaneous devices be wired to trip through the directional contacts?**

(5-1/61) *Question:* **In large paper mills the use of 13,800 v. as a primary distribution voltage has become quite prevalent. To accommodate the possible short circuit capacities in such systems the switchgear manufacturers have 15 kv. switchgear available with as much as 1000 mva. interrupting capacity and 80,000 amp. momentary rating. With systems such as this it is customary to supply the loads through load center unit substations. However, the primary interrupter switches for these substations cannot be obtained with sufficient momentary ratings to be compatible with those of the 15 kv. switchgear. Also current limiting fuses of sufficient interrupting capacity are not available in sizes above 100 amp. continuous. What is being done by the switchgear manufacturers to eliminate this deficiency?**

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The questions and answers marked with an asterisk are reproduced courtesy *Power* magazine.

Rosin in Paper and Paperboard

Proposed Revision of TAPPI Official Standard T 408 m-52.*

(THIS STANDARD IS UNDER THE JURISDICTION OF THE CHEMICAL METHODS COMMITTEE)

Rosin (colophony) is a natural resin extracted from the residue after the distillation of pine gum, tall oil or the solvent extract of pine stumps, knots, and top wood.

This method is for both the qualitative and quantitative determination of rosin in paper and paperboard. The qualitative tests indicate the presence or absence of rosin soap added as a sizing agent. The quantitative procedures give the total rosin, which consists of the natural resins in the pulp from which the paper was made plus any rosin added as sizing.

The procedures described are not applicable to the determination of synthetic resins (such as the melamine and urea formaldehyde resins used to impart wet strength properties to paper), but are limited to rosin.

QUALITATIVE TESTS

Apparatus

Crucible, porcelain, 35–50 ml.
Spotting Plate, porcelain or white glass with depressions

Reagents

Acetic Anhydride,
Sugar, nearly saturated solution of sucrose
Sulfuric Acid, concentrated H_2SO_4
Carbon Tetrachloride, CCl_4
Bromine, liquid
Phenol.

Liebermann-Storch Test

Place about 1 g. of the paper, cut into small pieces, in a clean, dry test tube. Add 5 ml. of acetic anhydride and boil down to about 1 ml. (*Caution*—since fumes of the anhydride are very irritating, the test should be made in the hood.) Pour the liquid residue into a clean, dry porcelain crucible and cool to room temperature or lower. If any waxy particles separate out, they should be filtered off on a small piece of filter paper previously wetted with acetic anhydride. Add carefully, down the side of the crucible, one drop of concentrated sulfuric acid. A fugitive, rose-violet coloration formed where the acid meets the anhydride, indicates rosin.

Raspail Test

Place the paper on a glass or porcelain plate and apply a drop of nearly saturated solution of sugar. After about 5 sec., remove the excess sugar solution with filter paper. Add a drop of concentrated H_2SO_4 to the sugar on the paper. A raspberry-red coloration indicates the presence of rosin.

Halphen-Hicks Test

This test consists of bringing a carbon tetrachloride extract of the specimen into contact with bromine vapor and seeing if a violet coloration forms. The reaction with common rosin is so intense that if present in any considerable amount, the color is apt to be masked. The test also can be applied to solid resins, varnishes, etc. The presence of more than a trace of water, alcohol or ether, interferes with the sensitiveness of the reaction.

Procedure

Prepare two solutions:

Solution A—1 part of phenol dissolved in 2 parts of carbon tetrachloride (parts by volume)

Solution B—1 part of bromine dissolved in 4 parts of carbon tetrachloride (parts by volume)

Place about 1 gm. of the paper, cut into small pieces, in a clean, dry test tube. Add about 3 ml. of solution A, shake or macerate with a stirring rod for several minutes. Pour the solution into one of the cavities of the spot plate until it just fills a depression; a portion of the solution will soon be seen to spread out on the flat part of the plate beyond the rim of the cavity unless too much of the CCl_4 previously has been lost through evaporation. If so, a drop or two more CCl_4 should be added to produce this spreading effect.

In an adjacent cavity of the plate, immediately place 1 ml. of solution B and cause the evolved bromine vapors to contact the surface of the solution in the other cavity, either by blowing a gentle current of air toward it or by covering both cavities with a watch glass.

The color reaction begins almost immediately, and the colors are best observed upon the flat portion of the test plate. They usually last long enough for satisfactory observation, and their changes are practically over in from 5 to 10 min.

If a green color develops which rapidly changes to

* The original of this revision was prepared by A. R. Reid, of the Hercules Powder Co., Wilmington, Del. This revision will be voted upon by the membership of TAPPI and minor changes may be made before publication in loose-leaf form.

blue and then violet, the latter lasting a considerable time, then slowly changes to purple, and finally and completely to a deep indigo, rosin is indicated.

The intensities of the colors and tints are, of course, dependent to a degree upon the concentration of the rosin dissolved in solution A, but with a little experience in the application of the test to materials of known purity, it is possible to interpret the indications without difficulty.

Different colors may be produced by different materials with these tests as follows:

Characteristic Colors

Material	*Liebermann-Storch*	*Halphen-Hicks*
Rosin	Fugitive violet to brown	Blue, finally indigo
Oxidized rosin	Fugitive violet to brown	Blue
Rosin glycerol ester	Fugitive violet to brown	Lavender-blue
Staybelite[a]	Fugitive violet to brown	Lavender-blue
Rosin maleate	Wine red changing to olive brown	
Beta-pinene polymer	Faint pink	Faint brown
Vinsol[b]	Weak purple	Green-Brown
Belro[c]	Weak purple-brown	Green-brown
Pine oil	Red-brown to blue-violet	
Turpentine	Faint yellow to red	. . .

[a] Pale-colored hydrogenated rosin.
[b] Aliphatic hydrocarbon-insoluble fraction of a solvent extract of aged pine stump wood.
[c] Dark rosin fraction from the solvent refining of wood rosin.

QUANTITATIVE DETERMINATION

The method depends upon the conversion of insoluble resinates to alcohol-soluble rosin followed by extraction. The conversion is effected by the action of hydrochloric acid of a definite concentration for a given time to limit the formation of other hydrolysis products. The dried extract is further extracted with anhydrous ether in which nonresinous materials, including starches and glues, are insoluble. If unsaponifiable waxes which may dissolve in anhydrous ether are also present, they are separated from the resinous material by saponification of the rosin. Further details are given in (*1*).

Qualitative tests may also be applied for the presence or absence of mineral matter which reacts with, or is dissolved by HCl, and for the presence of paraffin or a similar wax, to serve as guides for the subsequent analysis.

It has been found (*2*) that melamine formaldehyde resin does not interfere with the determination of rosin.

Apparatus

Extraction Apparatus, Soxhlet or Underwriters
Gooch Crucible, 30–50 ml. with fine-pore filter papers cut to fit
Suction Flask, for Gooch crucible
Beaker, 30–50 ml.

If waxes are also present:

Separatory Funnels, two 250-ml. or larger
Reflux Flask and Condenser, 250-ml. flask or larger
Steam Bath, for reflux flask

Reagents and Materials

Hydrochloric Acid, conc., and approx. 1*N* HCl
Extraction Solvent, mixture of 4 ml. of concd. HCl in 1 l. of 95% ethyl alcohol
Ether, diethyl, anhydrous, peroxide-free

If waxes are also present:

Potassium Hydroxide, 5% alcoholic solution KOH
Sodium Chloride, NaCl crystals
Sulfuric Acid, approx. 5 *N* H_2SO_4
Methyl Orange Indicator (see T 609 m.)

Test Specimen

For each test, prepare at least 10 g. of specimen about 0.25 by 1.6 in. (6 × 40 mm.), cut from representative samples taken in accordance with TAPPI Standard T 400 m. The paper should not be ground, since additional nonresinous materials may then be extracted.

Note: For paperboard, such as container board, pressboard, binders' board, and pasted board, it is advisable whenever possible to split the strips into thinner ones, after they have been weighed, to facilitate extraction of the resin.

Procedure

Allow the specimen strips to reach moisture equilibrium with the atmosphere of the balance and weigh 5 to 7 g. of strips to the nearest 0.01 g. Unless known to within 1%, determine the moisture content of a separate specimen similarly conditioned, according to TAPPI Standard T 412 m or T 484 m.

If the paper contains mineral matter reacting with or dissolved by hydrochloric acid, immerse the test specimen to be extracted in *N* HCl for 5 min., drain, wash free from acid, and dry at room temperature.

Crease the strips to be extracted with small zigzag folds and place them lengthwise in the syphon cup of the extractor, taking care to avoid packing them tightly together. To the extractor, add from 2 to 2.5 times the volume of the CCl_4, required to fill the syphon cup. Extract at a rate of 15 syphonings per hour (which should yield a volume of about 250 ml. of solvent distilled per hour) for a period of 2 hr. for uncoated or nonsurface-sized papers and 2.5 hr. for coated or surface-sized papers, or for paperboards. The extraction should not be continued much longer than specified, since resinous materials other than rosin might possibly be extracted and reported as rosin.

When the extraction period is completed, evaporate off the solvent in the flask on the steam bath, until the odors of alcohol and HCl are no longer noticeable. Place the flask in an oven at 105 ± 3°C. for 15 min., cool to room temperature, and add 20 ml. of anhydrous ether. The rosin should dissolve in from 5 to 30 sec. but if covered by foreign material, it must be uncovered by scraping the mass with a stirring rod. Unless the ether solution is clear, allow to stand 15 to 20 min. to further the coagulation and settling out of the foreign matter, then with suction, filter the solution, and that from rinsing the flask with less than 20 ml. of ether, through the good crucible with the fine-pore filter paper, transferring the solution to a carefully dried and weighed beaker. It is often necessary to refilter the solution through the same paper. After filtering, rinse the filter with less than 20 ml. of ether. Evaporate the ether in the tared beaker; then dry in an oven at 105 ± 3°C. for 15 min., cool, and weigh to the nearest 1 mg. Repeat the drying and weighing until the weight is constant to ±1 mg. (*Caution:* Do not place ether-wet material in an oven with exposed electrical contacts.)

If paraffin or similar waxes are present, after weighing the beaker plus rosin and wax, add about 25 ml. of approximately 0.5 *N* alcoholic KOH solution, heat to not

over 60°C. for 15 min., cool to room temperature, and transfer to a separatory funnel. Wash the beaker with about 25 ml. of ether and then with about 50 ml. of water, and add all washings to the separatory funnel. Add sufficient water or ether, or both, so that the funnel contains about 25 ml. of ether and 150 ml. of water. Shake the funnel well, add about 2 g. of NaCl, shake the funnel once more, and allow separation of the liquids. Draw off the water solution into another separatory funnel and wash with 25 ml. of ether. Drain the two ether solutions into the weighed beaker, wash both funnels with about 20 ml. of ether, adding the washings to the beaker, and evaporate the ether. Dry the container and residue at 105 ± 3°C. (see note) for 15 min. cool, and weigh to the nearest 1 mg. Repeat the drying and weighing until the weight is constant to ±1 mg. The material thus obtained will be paraffin or similar wax, plus the unsaponifiable material from the rosin, which, for most purposes and in the absence of definite knowledge regarding the particular rosin in the paper under test, may be assumed to be 5% of the rosin in the paper. To obtain the weight of the rosin therefore, divide the weight of the combined rosin and wax, less the weight of the wax, by 0.95.

Note: If the paper contains waxes or oil volatile at 105 ± 3°C. and it is not practicable to dry the residue at a lower temperature, separate the rosin from the oil by saponification and determine it directly, as prescribed in the following alternative method.

Alternative Treatment of Rosin-Wax Extract Where a Direct Determination of the Rosin is Desired

Wash the weighed rosin-wax residue obtained from the alcohol-extracted paper into a wide-mouthed flask, using about 25 ml. of ether. Add about 25 ml. of approximately 0.5 *N* alcoholic KOH and about 100 ml. of water. Heat the contents of the flask to boiling under a reflux condenser for 30 min., cool to room temperature, add about 25 ml. of ether, transfer to a separatory funnel, and wash the flask first with water and then with ether, adding the washings to the funnel. Add about 2 g. of NaCl to the separatory funnel, shake well, and let the liquids separate. Draw off the water solution into a beaker. Add 50 ml. of water and about 2 g. of NaCl to the ether solution in the separatory funnel, shake well, allow separation of the two liquids, and draw off the water solution adding it to the first water solution.

Add to the combined water solutions 2 drops of methyl orange indicator solution; carefully acidify by adding 5 *N* H_2SO_4 until the solution is definitely pink, and then add 1 ml. more of the acid. Cool the solution to room temperature, transfer to a separatory funnel, add 25 ml. of ether, and wash the beaker with about 10 ml. of ether, adding the washings to the funnel. Add about 5 g. of NaCl, shake the funnel well, allow separation of the liquids, draw off the water solution into another separatory funnel, and wash it twice more, using about 20 ml. of ether each time. Transfer all ether solutions to a weighed beaker, washing all containers with ether. Evaporate the ether, dry in an oven at 105 ± 3°C. for 1 hr. and weigh to the nearest 1 mg. Repeat the drying and weighing until weight is constant to ±1 mg. The weight of the rosin thus found is assumed to be 95% of that in the paper.

Note: If the paper contains saponifiable fats or greases in addition to rosin, the alternative method described above will give results higher than the true rosin content as they will be included with it. In this case, the analyst may apply such modifications to the method as are considered justifiable, and the report should state what modifications of the standard method were used.

Report

Report the result as the average of at least two determinations to the nearest 0.1 as a percentage by weight of the moisture-free paper.

Precision

The results of duplicate determinations may be expected to agree within 0.2%.

ADDITIONAL INFORMATION

1. This revision adds the Halphen-Hicks test and color reactions for it and the Liebermann-Storch test.
2. Related methods: ASTM D 549.

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RECENT BOOKS

Principles of Unit Operations. By A. S. Foust, L. A. Wenzel, C. W. Clump, L. Maus, and L. B. Anderson, Lehigh University. John Wiley & Sons, New York, 1960. Cloth, $8\frac{1}{2} \times 11$, 578 pages. $15.

The authors, being familiar with the traditional approaches made by previous authors to the unit operations aspect of chemical engineering endeavors to offer a new approach. The treatment in this book emphasizes the scientific principles upon which the principles are based and groups those with similar physical base so that they may be considered together.

This novel form of treatment is offered in the belief that it is more efficient in teaching, more economical in time, more adequate in presentation of the fundamentals, and more effective in training toward the definition and solution of broad problems in chemical processing. The three major categories under which the authors assign the unit operation are stage operations such as phase relationships and mass transfer operations; molecular and turbulent transport such as interphase transfer; and applications to equipment design such as heat transfer, evaporation, compressors, and pumps.

RC 292. Determination of Specific Gravity of Liquid Resins (Hydrometer Method)

The object of this method is to provide a uniform means for measuring the specific gravity of liquid resins. This method was adopted by the West Coast Adhesive Manufacturers in 1957 as a standard for this determination.

Apparatus

1. Hydrometer cylinder 14 in. high and 2 in. diam. such as No. 24660 in Scientific Supplies Catalog.
2. Hydrometers such as those manufactured by Taylor Permax, calibrated at 21°C./21°C., in the following ranges:

0.950–1.000	1.150–1.200
1.000–1.050	1.200–1.250
1.050–1.100	1.250–1.300
1.100–1.150	1.300–1.350

Procedure

1. Fill the clean, dry hydrometer cylinder to within about $1^1/_2$ in. from the top with resin.
2. Adjust the temperature of the resin to 21°C. Make sure the temperature is uniform from top to bottom.
3. Place the appropriate 21°C./21°C. hydrometer in the resin and allow it to come to rest. Push the hydrometer down slightly below the rest point to wet the stem.
4. When the hydrometer has returned to rest, take the reading where the flat surface of the liquid intersects the stem. This is usually best done by sighting under the surface of the liquid, with a flashlight, if necessary. If it is not possible to see through the resin, a correction of 0.001 is added to the reading at the point where the resin reaches its maximum height on the hydrometer stem. (Drifilm, a General Electric product, may be used to treat the hydrometer. This will give a flat meniscus for easy reading.)
5. The results are reported as specific gravity at 21°C./21°C.

Note: For purposes of standardization the specific gravity is reported at 21°C./21°C. If the hydrometer used is calibrated at a different temperature, it is necessary to apply a correction to the reading. The correction is determined by first knowing the specific gravity of the resin at 21°C./21°C. determined by the pycnometer method (RC 291). The hydrometer is then read in the same resin at 21°C. The difference between the pycnometer value and the hydrometer reading is the correction to be applied each time the hydrometer is used in similar resins.

RC 293. Measurement of pH of Liquid Resin Syrups

This method is satisfactory for pH measurements on all liquid resin syrups except for those with a pH 11 or over (see RC 294 for high pH measurements). This was adopted by the West Coast Adhesive Manufacturers in 1958 as a standard for this determination.

Apparatus

1. A pH meter with standard reference and glass electrodes accurate to ±0.03 unit such as: Beckman, Models H-2, G, GS, W or N, and Zeromatic; Leeds and Northrup, Model 7664.
2. Standard buffer tablets or solutions at pH 3, 4, 5, 6, 7.0, 8, 9, 10.0, and 11.
3. Thermometer.
4. Distilled water and wash bottle.

Procedure

A. *Meter Adjustment.* Standardize the meter as outlined in the manufacturer's instructions. Standardize at both pH 7.0 and 10.0 at 21 ± 1°C. adjust range if necessary to produce accurate readings at both points. Use 7.0 and 10.0 buffer solutions freshly taken from the original container, or in the case of tablets, prepared not over one week earlier. Standardize the meter once every 8 hr. of use.

B. *Measuring pH of Samples.* With the meter accurately standardized, check and perform fine adjustment against a standard buffer solution at a pH within 1 unit of the test sample. If the fine adjustment requires over 0.1 unit correction, restandardize as in part A.

Read the sample pH to the nearest 0.05 unit. Agitate with glass stirring rod before and after immersion of clean electrodes. Avoid transferring any "skin" on the resin surface to the electrodes. Swirl gently. Maintain sample at 21 ± 1°C. Report as pH at 21°C.

Note: During all standardization, adjustment, and reading steps, it is essential that proper electrode care and cleaning techniques be observed:

1. Glass electrodes are immersed in clean distilled water for at least 4 hr. before use and continuously between readings.
2. Calomel half cell electrodes having flowing potassium chloride capillaries are flushed before each reading.
3. After each immersion in buffer or sample, the electrodes are thoroughly washed, using gentle finger motion to dislodge viscous syrups, and finishing with a thorough distilled water rinse.
4. Before immersion in buffer or sample, the electrodes are gently blotted of excess distilled water (from rinse or soak) with paper tissue.

RC 294. Measurement of pH of Liquid Resin Syrups at pH 11 or Higher

This method is used in lieu of RC 293 with highly alkaline resin systems. This method was adopted by the West Coast Adhesive Manufacturers in 1958 as a standard for this determination.

Apparatus

1. A pH meter accurate to ±0.03 unit such as: Beckman, Models H-2, G, GS, W or N, and Zeromatic; Leeds and Northrup, Model 7664.
2. Reference electrode. Standard, either fiber or silicone sleeve type.
3. Glass electrode. Beckman type E-2 blue glass.
4. Standard buffer tablets or solutions at pH 11 and 12.45.
5. Thermometer.
6. Distilled water and wash bottle.

Procedure

A. *Meter Adjustment.* Standardize the meter as outlined in the manufacturer's instructions using pH 11 or pH 12.45

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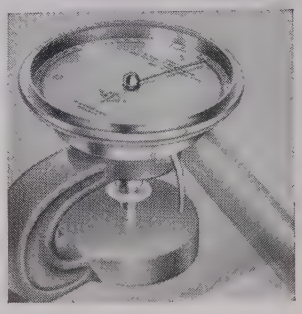

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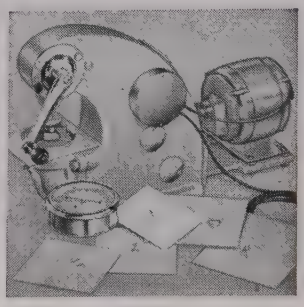

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buffer as appropriate. Use freshly prepared buffer solution and read pH at 21 ± 1°C. Frequent standardization of the electrodes is essential.

B. *Measuring pH of Sample.* Read the pH of the sample at 21 ± 1°C. immediately after standardization. A gradual increase in the indicated pH may occur for about 5 min., followed by a gradual decrease in highly alkaline solutions. The maximum reading is reported as the pH at 21°C. Check the accuracy of the reading against the standard buffer solution at 21 ± 1°C.

If the sample pH is higher than the buffer solution pH, a correction, based on the sodium-ion concentration, can be used for greater accuracy. A chart for estimating this correction is available from the electrode manufacturer.

Note: During all standardization, adjustment, and reading steps, it is essential that proper electrode care and cleaning techniques be observed.

1. New glass electrodes, or electrodes which have dried out, should be soaked for several hours in pH 10 buffer solution. Normally, glass electrodes are immersed in clean distilled water for at least 4 hr. before use and continuously between readings.
2. Calomel half cells having flowing potassium chloride capillaries are flushed after each reading.
3. After each immersion in buffer or sample, the electrodes are thoroughly washed, using gentle finger motion to dislodge viscous syrups, finished with a thorough distilled water rinse.
4. Before immersion in buffer or sample, the electrodes are gently blotted of excess distilled water (from rinse or soak) with paper tissue.

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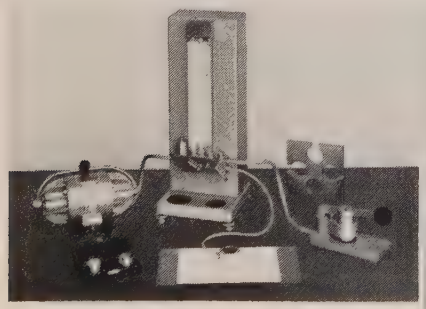

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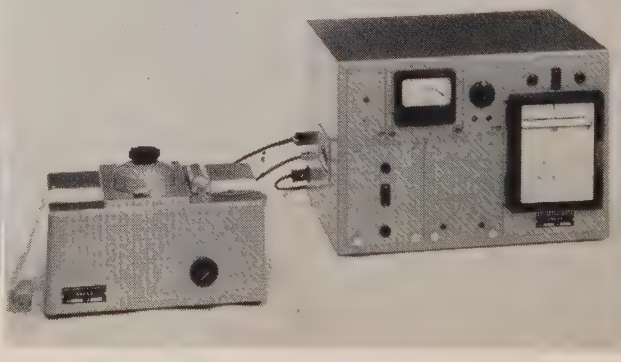

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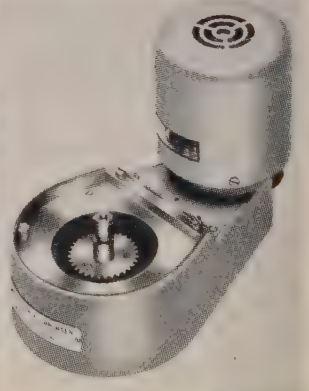

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LOCAL SECTION ACTIVITIES

Meeting Calendar

January, 1961

17 Indiana District of the Ohio Section, Marott Hotel, Indianapolis, Ind. Joint Meeting—Am. Society of Quality Control, "What's Important in Quality Control," R. Hicks, Purdue University.

17 Pacific Section, Tacoma, Wash., "Process and Quality Control Techniques."

19 Kalamazoo Valley Section, Hotel Harris, Kalamazoo. Annual Papermaker's Get-Together.

20–21 Southeastern Section, Francis Marion Hotel, Charleston, S. C.

26 Delaware Valley Section, Engineers Club, Philadelphia, Pa. "Packaging."

26 Golden Gate Section, El Rio Hotel, Antioch, Calif.

February, 1961

2 Lake Erie Section, Plant Tour—Food Processing Co., Cleveland, Ohio.

3 Central District, Empire State Section, University Club, Syracuse, N. Y., "Natural Resources of New York State as related to the Pulp and Paper Industry," by Assemblyman R. W. Pomeroy and N. J. Stout.

3 Gulf Coast Section, Birmingham, Ala.

7 Chicago Section, Chicago Bar Association, 29 S. La Salle St., Chicago, Ill. "The Development of Plastics as a Packaging Medium."

9 Ohio Section, Manchester Hotel, Middletown, Ohio. "Trailing Blade Coating," by H. M. Annis, Oxford Paper Co.

9 Northern District, Empire State Section, Hotel Woodruff, Watertown, N. Y.

14 Indiana District, Ohio Section, Marott Hotel, Indianapolis, Ind. "Quality Control in Practice," Panel Discussion.

March, 1961

2 Lake Erie Section, Cleveland, Ohio. "Paper and Paper Technology and Paper—Its Future as a Profession."

3 Central District, Empire State Section, University Club, Syracuse, N. Y. "New Developments in Corrugated Boxes," by P. Palmaccio, Mead Corp.

7 Berkshire District, New England Section, Wendell-Sherwood Hotel, Pittsfield, Mass.

7 Chicago Section, Chicago Bar Association, 29 S. LaSalle St., Chicago, Ill., New Developments in Coatings & Coating Equipment."

9 Northern District, Empire State Section, Hotel Woodruff, Watertown, N. Y.

10 Virginia-Carolina Section, John Marshall Hotel, Richmond, Va., Dinner Meeting.

13 Bay District, New England Section, Armand's Beacon Terrace, Framingham, Mass.

14 Metropolitan District, Empire State Section, 465 Lexington Ave., New York, N. Y. "The Paper Industry in Europe," by A. W. Wilson, Editor, *Pulp and Paper*.

14 Lake State Section, Kaukauna Elks Club, Kaukauna, Wis.

14 Ohio Section, University Center, Miami University, Oxford, Ohio. "Appearance Properties of Paper," by Richard Hunter, Hunter Associates Laboratory.

16 Kalamazoo Valley Section, Inman's Restaurant, Galesburg, Mich. Joint Meeting PIMA-TAPPI-Craftsmen on Graphic Arts.

17–18 Delaware Valley Section, Benjamin Franklin Hotel, Philadelphia, Pa. Philadelphia Graphic Arts Conference.

21 Golden Gate Section, Crown Zellerbach Bldg., San Francisco, Calif.

21 Pacific Section, Longview, Wash. Shibley Award Meeting.

21 Indiana District, Ohio Section, Marott Hotel, Indianapolis, Ind. Education Committee Meeting, "Who We Are and What We Do" (Indiana High School Science Teachers as guests), Dr. Alfred H. Nadelman, Western Michigan University.

24–25 Southeastern Section, Bon Air Hotel, Augusta, Ga. Tour of Continental Can Co. paper mill.

April, 1961

4 Chicago Section, Chicago Bar Association, 29 S. LaSalle St., Chicago, Ill. F.D.A. (Tentative, will hold if warranted).

6 Lake Erie Section, Cleveland, Ohio. "The Advantages and Disadvantages of Letterpress and Flexography."

6 Kalamazoo Valley Section, Inman's Restaurant, Galesburg, Mich. Visit to Michigan Carton Co.

7 Central District, Empire State Section, University Club, Syracuse, N. Y. Senior Night–Junior Awards.

7 Gulf Coast Section, Pine Bluff, Ark.

10 Pioneer Valley District, New England Section, Storrowton Tavern, West Springfield, Mass. Management night.

11 Metropolitan District, Empire State Section, 465 Lexington Ave., New York, N. Y. "The Reused Fiber."

11 Lake States Section, Menasha, Wis.

13 Ohio Section, Tour National Cash Register Co. at Dayton, Ohio.

13 Northern District, Empire State Section, Hotel Woodruff, Watertown, N. Y. Joint meeting with Beaver Falls Chapter, A.I.C. "The Planning of a Technical Center," by K. A. Arnold, St. Regis Paper Co.

18 Indiana District of the Ohio Section. Plant Tour, Container Corp. of America corrugating medium mill, Carthage, Ind. Dinner at Durbin Hotel, Rushville, Ind. "Machinery of Paper—Part III–Beater Room Equipment," N. S. Balfour, Beveridge Paper Co.

27 Delaware Valley Section, Engineers Club, Philadelphia, Pa. Program on wet end retention by The Institute of Paper Chemistry.

May, 1961

2 Chicago Section, Chicago Bar Association 29 S. LaSalle St., Chicago, Ill. "Structural Design: Corrugated & Folding Cartons."
4–5 Pacific Section, Harrison Hot Springs, Canada.
5 Central District, Empire State Section, Syracuse, N. Y. Ladies' Night.
9 Golden Gate Section, Claremont Hotel, Berkeley, Calif.
11 Northern District, Empire State Section, Hotel Woodruff, Watertown. Annual Ladies' Night.
11 Ohio Section, Hartwell Recreation Hall, Cincinnatti, Ohio. Ladies' Night.
11 Lake States Section, Green Bay, Wis.
16 Indiana District, Ohio Section, Marott Hotel, Indianapolis, Ind. "FDA Regulations—Current Status."
19 Metropolitan District, Empire State Section, Tavern on the Green, New York, N. Y. Ladies' Night.
19–20 Southeastern Section, General Oglethorpe Hotel, Savannah, Ga.
25 Delaware Valley Section, Engineers' Club, Philadelphia, Pa. E. J. Albert Award.
25 Kalamazoo Valley Section, Gull Harbor Inn, Gull Lake, Joint PIMA-TAPPI Recognition Night.
25 Delaware Valley Section, Philadelphia, Pa.
26–27 Gulf Coast Section, New Orleans, La.
Virginia-Carolina Section, Dinner Meeting and Mill Tour.

June, 1961

8–10 Empire State Section, Whiteface Inn, Whiteface, N. Y.
9–10 New England Section and Maine-New Hampshire Section. Joint Meeting. Wentworth-by-the-Sea, Portsmouth, N. H.
10 Lake Erie Section, Cleveland, Ohio. Annual Dinner Dance, Greenbriar Restaurant, Parma Heights, Ohio.
20 Kalamazoo Valley Section, Gull Lake Country Club, Gull Lake. Joint TAPPI-PIMA fun day.
20 Indiana District, Ohio Section, Anderson Country Club, Anderson, Ind. Fourth Annual Golf Outing.

June, 1962

1–2 New England Section, Chatham Bars Inn, Chatham, Mass.
7–9 Empire State Section, Whiteface Inn, Whiteface, N. Y.

June, 1963

6–8 Empire State Section, Whiteface Inn, Whiteface, N. Y.

June, 1964

11–13 Empire State Section, Whiteface Inn, Whiteface, N. Y.

Ohio

Dr. Lennart G. Stockman of the Central Laboratory of the Swedish Cellulose Industry spoke to 118 persons attending the September 13 meeting of Ohio TAPPI at the Manchester Hotel in Middletown.

After briefly reviewing the history and present status of sulfite pulping, he discussed in detail two areas of the process in which he believed significant improvements will be realized in the near future. Changes in methods of chipping are expected to reduce the loss of pulp strength attributable to the bruising of ends of chips by current production methods. Affect of the bruising was explained as a bending of rigid lignified fibers under pressure resulting in more areas of amorphous cellulose in the fiber structure. These areas hydrolize more readily in the conventional low pH sulfite cook and thus present weakened spots in fibers. Sulfite pulp thus becomes a "too easy beating pulp." Short fibers occur and drainage decreases too rapidly with refining so that optimum strength development is inhibited.

Progress on this problem was evidenced by mention of mills that are obtaining greater pulp strength as a result of changes only in chipping methods. One specific example was a new flake or wafer type of chip.

A second major area of progressing improvement in the sulfite process is the use of soluble bases. Ammonia base, for example, instead of the conventional calcium gives more rapid delignification. Higher pH cooking becomes possible as well as two-stage pulping which permits better control of hemicellulose losses. A mill in Sweden was cited as currently obtaining a good glycine pulp by first stage modifications and a good opacity pulp by second stage modifications.

In summary, continued efforts in these two areas should provide sulfite pulp with better strength, opacity, and reportedly better formation qualities.

It is hoped that Dr. Stockman will have available at an early date a copy of his interesting talk so that it can be submitted in its entirety.

A distinguished guest at the meeting was Mr. R. G. Macdonald of National TAPPI who spoke briefly to the group.

October Meeting

Afternoon seminars, a Research Center tour, and an evening address by Dr. Edward J. Jones made up the October 13 meeting of the Ohio Section of TAPPI in Middletown, Ohio. Over 200 persons attended the day's activities organized by the Ohio Section with the cooperation of The Black-Clawson Co. who sponsored a noon luncheon and predinner social hour. After welcoming remarks by Charles S. Swietzer, Ohio Section chairman, the three concurrent seminars convened.

The session on continuous pulping was moderated by Dr. John N. McGovern who remarked that there is apparent good agreement now that the pulping of wood and other fibrous materials can be performed more advantageously continuously than batch-wise. Many advantages are well established such as (1) uniform steam, power, and liquor demands; (2) lower "within the process" materials and storage; (3) rapid adjustments to variations and, hence, more uniform overall

Continuous pulping panel: Laundrie, R. Green, J. McGovern, R. Fuller

Wastepaper utilization panel: F. Bathon, R. Bowen, E. T. Luey, C. Coffman

Vokes Rotor demonstration during Ohio TAPPI tour of Black-Clawson Research Center

products; and (4) the possibility of lower labor and wood and chemical cost. These and other advantages and disadvantages were discussed by the panel speakers in their presentations which followed.

James Laundrie (U. S. Forest Products Laboratory) talked about the many aspects of continuous cold soda pulping. Robert Green (Champion Paper & Fiber Co.) discussed the advantages of continuous production of neutral sulfite semichemical pulp. Robert Fuller (Gulf States Paper Corp.) spoke on continuous kraft pulping. In an active question-and-answer period which followed, the panel members gave some interesting comparisons of features common to the three pulping processes such as bleaching considerations, equipment maintenance, chip size, and labor requirements.

The panel discussion of wastepaper utilization was presided over by E. T. Luey (Boxboard Research Institute). Panelist Cletus Coffman (Chesapeake Paperboard Co.) discussed new arrangements of equipment for improved preparation of filler stocks. Robert Bowen (Alton Box Board Co.) attempts to standardize fiber blends for box board furnish through greater control of wastepaper treatment and increased use of virgin short fiber pulps. Francis Bathon (Elk Paper Manufacturing Co.) outlined the phases of his company's newly acquired process incorporating the Petro Diffusion system for coping with foreign materials in waste furnish.

A seminar on stock preparation was moderated by E. N. Root (Black-Clawson). Edmund B. Becker (J. P. Lewis Co.) described the use of a Sydrapulper for defibering at his boxboard mill. Dean Kohlhepp (Black-Clawson) explained the development of increased efficiency in Hydrapulpers through the use of the new Vokes Rotor. Douglas Sutherland (Black-Clawson) discussed advances in disk refining of short fibered pulps.

Pilot model equipment in actual operation was observed by the group in touring the new Black-Clawson Research Center. Of particular interest was the pilot system for producing wood pulp by the new ChemPreg cold soda pulping process. Also on display was a laboratory scale, experimental paper machine of radical design, on which Black-Clawson is testing the feasibility of forming a sheet of paper vertically.

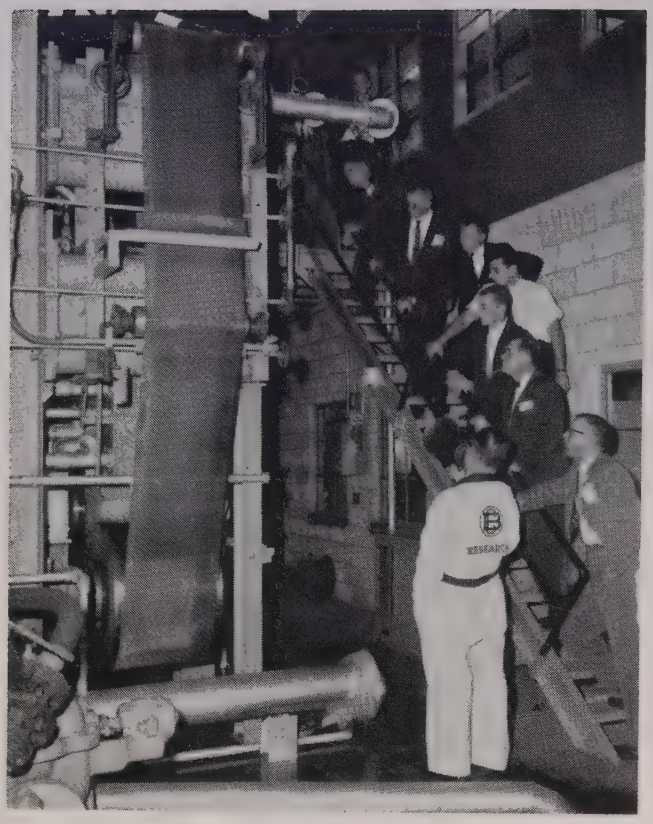
Dr. Edward J. Jones of The Institute of Paper Chemistry discussed "New Approaches to Pulp Evaluations" in his after-dinner address. He reviewed the Institute's program devoted to fiber and fiber-water systems in which 45 pulp and paper manufacturers cooperate. Current research approaches include chemical properties, fiber dimensions, fiber strength, pulp filtration, and fiber flexibility.

An example of the results of their work was a contribution to the concept of fiber strength. Handsheets of tagged fibers were torn and fibers at the break were examined. Tensile breaks were examined microscopically. It was found that 70 to 80% of the fibers break in a tensile break, others only pull out. This shifted the emphasis on single fiber strength which previously was not believed to be too important.

Problems and progress with the zero span tensile test were

Stock preparation equipment panel: D. Kohlhepp, E. Becker, D. Sutherland, E. Root

Demonstration of ChemPreg cold soda pulping system, Black-Clawson Research Center, during Ohio TAPPI visit



Experimental vertical paper machine, Black-Clawson Research Center, is viewed by visiting Ohio TAPPI members

mentioned. Completed work in redesigning the instrument is to be published in the near future.

Variables of fiber bonding that are being pursued currently are surface area available for bonding, surface area bonded, and bond strength. The significance of this work was emphasized by a paper published in 1959 on the "structural aspects of bonding." With single fibers bonded at many points, individual fiber break is the only possible means of sheet fracture. An example of difficulty in some approaches to these questions is the fact that it is not possible to use an election microscope with wet fibers. It can be used with dry fibers only.

Progress in investigations of fiber surface area was evidenced by the fact that 15 years ago there was no acceptable method of measurement. Now there are a number of useful techniques. They include geometric or microscopic method,

Luncheon head table: F. Cessna, R. Vokes, E. P. Espenmiller, O. Hein, J. Baxter

Luncheon head table: E. Suchecki, T. Weisman, P. Westfall, E. Root, B. Bailey, C. Sweitzer

silver technique, water filtration resistance, dye adsorption, and gas absorption. Each of these has a critical application. A more recent secondary technique is light scattering of a finished sheet of paper. The concept involved here is that two cellulose surfaces not in contact will scatter light. An interesting application is a comparison of the strength of a sheet to its light scattering ability.

Examples of the practical significance of some of the current Institute research programs emphasized the benefits the industry should be realizing in the future as a result of their efforts.

THOMAS H. WEISMAN, *Recording Secretary*

Lake States

The Lake States Section of TAPPI met on Nov. 16, 1960, and approximately 200 people went through the Nicolet Paper Co. at West DePere to view the new paper machine. This was a joint meeting with the Winnebago Section of the American Society For Quality Control.

After the tour, an afternoon session was held at the Green Bay Elks Club. Harry H. Hull, creative engineer in Research for the R. R. Donnelley & Sons Co. in Chicago, presented a talk on the design of experiments. Dinner was served at the Elks Club at 6:00 p.m., and in the evening, Dr. Paul S. Olmstead, consultant in Engineering Statistics for the Bell Telephone Laboratories, Whippany, N. J., talked on statistical quality control in engineering research and development.

J. F. WHALEN, *Secretary*

Chicago

On October 4, Chicago Section of TAPPI held their monthly meeting. In addition to local members and guests we had with us: Philip Nethercut, Executive Secretary, National TAPPI; James Field, National TAPPI; Peter Dickie, Pacific Section chairman; Gordon Pixler, Lake Erie Section; Charles Eberly, chairman, Indiana District, Ohio Section. The meeting was devoted to "New Ideas in Corrugated" with Roy Caponi of Union Bag-Camp Paper Corp. as moderator.

A. W. Asconi of Liberty Engineering Co. spoke on the Maxwell Glue Rite machine. This is a new unit which can be used in conjunction with the Bowie folder for making the lap joint or manufacturers joint or corrugated cases. Features of the Glue Rite machine are low initial cost with very short setup time required.

Donald Hager of American Viscose Corp. spoke on Avisstrap, a new rayon strapping. This material features ease

Group at the October meeting of the Chicago Section

of handling, safety, and economy. Uses in general are the same as for steel strapping.

Harvey Taylor of Dorr Sales and Engineering Co. spoke on the Dorr rapid mounting device. This device reduces the down time for set up to a degree equal to another printer slotter. In addition it offers means of control registration with a quick set up device.

P. M. Gronendyke

New England (Berkshire District)

The first 1960 meeting of The Berkshire District of the New England Section of TAPPI was held at the Pittsfield Country Club, Pittsfield, Mass., on Nov. 1, 1960. A problem session on consistency regulators was conducted previous to the meeting. The problem session is a new concept in our meetings, and was inaugurated in an attempt to help solve general mill problems. About 30 attended the problem session. Representatives of three regulator manufacturers, DeZurik, Fischer-Porter, and Krofta were present and joined in the discussion. The sensitivity of various controllers, methods of installation, variables affecting the measurement, and proper method for sampling of consistency were discussed.

A cocktail hour and dinner followed the consistency discussion. After dinner, Dr. William Selke, research director of Peter J. Schweitzer Div. of Kimberly-Clark Corp. gave an interesting talk on fiber selection in the design of paper. He stated, by analogy to other engineering materials of construction, that paper should be engineered for proper performance in the end use at minimum cost. The given job may sometimes be done with fibers which cost more per pound than wood pulp, but have properties which justify the cost. Dr. Selke illustrated by derivation and formula some of the fiber properties which could be precalculated and pre-engineered into the final sheet. He also topically demonstrated the different properties of kraft and orlon fibers by showing papier-mache heads of a donkey and an elephant, respectively, in which the suppleness of the trunk was derived from the synthetic fiber used to make the elephant head.

Dr. Alfred Marzacchi, of Owens-Corning Fiberglas Corp. then spoke on the development, properties, and application of glass fiber and glass flake. An interesting series of slides were shown illustrating glass fiber properties and manufacture. Dr. Marzacchi pointed out that glass flake is in the same position as glass fiber some years ago, with great skepticism as to its utility. However, in the laboratory they have made interesting electrical insulation papers with this material. Leslie Warner, also of Owens-Corning, joined in the discussion during the question and answer period.

Milton J. Gordon, *Assistant Secretary*

Kalamazoo Valley

The first meeting of the new season for the Kalamazoo Valley Section was held in conjunction with the Eleventh Testing Conference at the Civic Auditorium, Grand Rapids, Mich., on Sept. 28, 1960. Two hundred seventy-five attended the evening banquet to hear Walker L. Cisler, president of The Detroit Edison Co.

Mr. Cisler's presentation, "The Present Status Of Atomic Power Development," reviewed the activities of regional, national and international development efforts. "One-quarter of the world's almost three billion people use four-fifths of the available energy. The other three-quarters are impatient to claim and to use their proportionate share." Mr. Cisler urges international communication and cooperation between all intelligent men who share technical interests. From such cooperation will result—"the development of peaceful uses of the earth's magnificent resources."

The complete text of this talk has been published in the December issue of *Tappi*.

Arthur H. Hupp, *Secretary*

Delaware Valley

The first meeting of the Delaware Valley Section for the 1960–61 season was held on Sept. 14, 1960. As is the custom at opening meetings of the Delaware Valley Section, a plant tour was held. On this occasion, tours of the Hamilton Paper Co. in Miquon, Pa., were conducted between the hours of 2 and 4 p.m.

After visiting the facilities of the Hamilton Paper Co., a social hour and dinner meeting were enjoyed at the Anchorage Inn in Philadelphia.

The high light of the dinner meeting was a talk given by Dr. Lennart G. Stockman of the Swedish Central Laboratory on the subject "The Quality of Sulphite Paper Pulps." An interesting discussion period followed the presentation.

Philip A. Cerasoli, *Secretary*

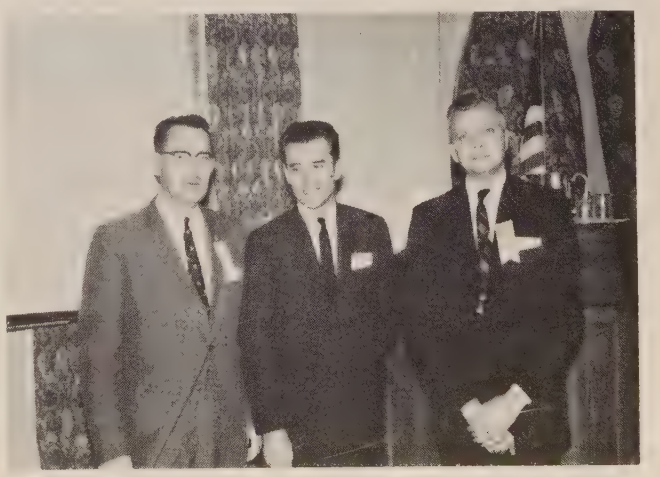
October Meeting

The October meeting of the Delaware Valley Section was held on Thursday, October 27, at the Engineers' Club in Philadelphia.

"Package Design and Corporate Image" was the title of the talk presented by William F. Meyer, Jr., eastern regional director of the Design Laboratory, Container Corp. of America, Valley Forge, Pa.

A resume of Mr. Meyer's talk follows.

The basic facts of life in marketing today indicate that it is a highly competitive market. People—the fact that they work hard, play hard, and demand high standards of living with



A. L. Saindon, Jr., Curtis Paper Co.; W. F. Meyer, Jr.; and C. A. Wynn, Container Corp. of America

Dr. Yale Brandt of Reynolds Metals Co. presenting his paper "Aluminum Foil Laminations." Shown are: Garland Edmonds, Chesapeake Corp., vice-chairman of the Virginia Carolina Section; Dr. Brandt; K. F. Adams, executive vice-president of Halifax Paper Co.; and James Field of National TAPPI

built-in convenience features—all add up to a vigorous marketing challenge.

Production, distribution, and sales are three key factors in the current business world. With a high point of efficiency having been attained in production and distribution, the question is "How can sales be increased at a profitable margin?" Being able to produce more than can be consumed, and being able to get the product to the market, the problem then presents itself—how can the product be promoted and sold once it is presented to the consumer?

Promotion and sales are plagued by the scourge of sameness. At the point of sale, all packages and brands face the great changes of looking alike in retail outlets that use the same type of lighting, display, and interior decorating. Here the problems of sameness require that a product reflect the criteria developed through advertising, such as quality, appetite appeal, tradition, etc.

To aid in overcoming sameness and establishing product association, research techniques have been developed which include scientific perceptual testing as well as attitudinal studies and field surveys. A designer must recognize the importance of research and be willing to use the facts presented. Thus armed with a knowledge of marketing, merchandising, and research techniques the designer must then apply the basic principles of good design to a package or product so that it can effectively communicate or sell itself at the point of sale.

The ideas of a designer must move within a maize of production techniques, complexity of production materials, and the methods of printing as applied to the many materials available in the packaging field. Above all, in packaging, problems must first be defined before they can be solved. If they are properly defined they can be solved by a creative designer who has the experience and the basic knowledge of many of the points included in this discussion.

Aluminum Foil Laminations

Y. M. Brandt

The purpose of this talk is to give you, as potential users of aluminum foil and as potential suppliers of paper for conversion into foil laminated products, a better understanding of what foil can do and how the various laminations are made.

Aluminum foil has properties that make it very desirable for use in both industrial and packaging applications. Certainly one of the most prominent of these properties is evident to any of us who have the opportunity or chore (depending on your point of view) of negotiating the aisle of a modern supermarket. The array of colors and bright flashes of metal are readily apparent as one traverses the length and breadth of these monuments to our modern marketing techniques. The decorative applications of foil are well known and widely used.

There is no doubt that aluminum foil has eye appeal. It can, and will, attract customers to the product when it is artfully and tastefully used. The success of the foil wrapper for bar soap is a well documented and widely publicized example of aluminum foil's ability to attract Mrs. Consumer.

Aluminum foil has been proved by market survey to give the connotation of "quality" to the product even though it may only be used as a label. The extensive use of foil in the beverage label field is evident everywhere.

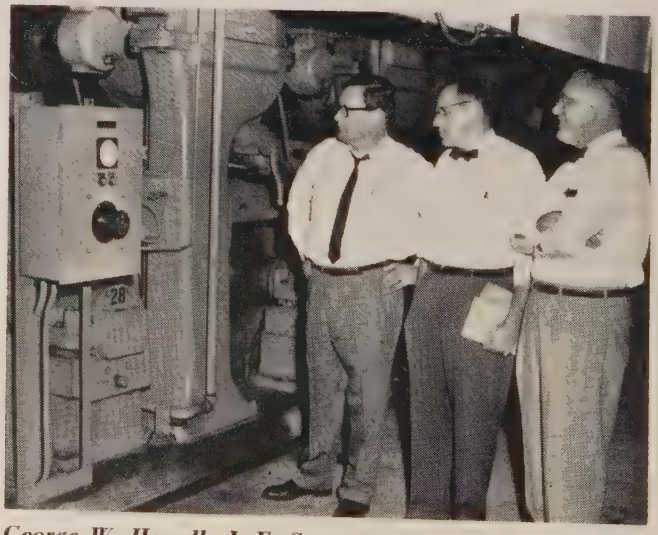
Aluminum foil has consumer acceptance. This is attested to every day as the consumer consumption of all types of household foil continues to grow.

At the present time some 160 million rolls of household aluminum foil are consumed in the United States annually in one or all of the 1001 possible uses that have been found for this versatile material.

Thus, aluminum foil's eye appeal, quality connotation, and consumer acceptance coupled with today's printing

Table I

1. Low moisture and gas transmission rate
2. Greaseproofness
3. Odorless, tasteless, nontoxic, and clean
4. Nonabsorptive
5. Impervious to light and odors
6. Not subject to attack by many foods and nonfood products
7. Can be readily combined with various papers, cloths, and plastic films
8. Can be readily coated and printed
9. High reflectivity—low emissivity
10. High conductivity
11. Noninflammable
12. High tensile strength
13. Good moldability when fully annealed
14. Light in weight
15. Does not rust
16. Low cost
17. Good availability
18. Easy to handle and adaptable to production machines
19. Good low temperature properties
20. Radiation permeability
21. Does not support fungus and bacteria growth
22. Resistant to insect infestation
23. Dimensional stability



George W. Howell, J. F. Stevenson, and Don Estebo, all of Meade Corp., Lynchburg, Va., looking over Halifax Paper Co.'s new no. 4 paper machine, the Dixie Queen

Y. M. Brandt, Packaging Research Div., Reynolds Metals Co., Richmond, Va.

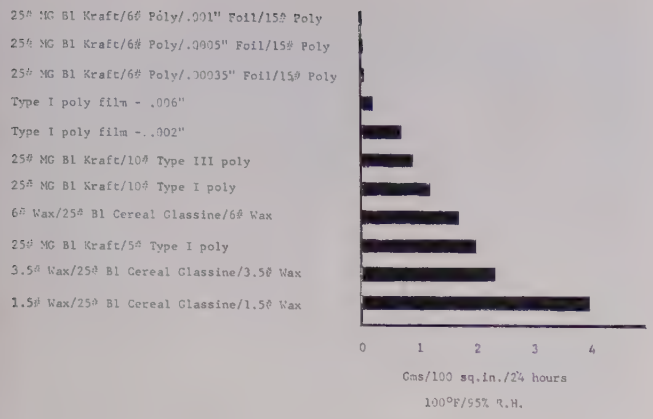

25# MG Bl Kraft/6# Poly/.001" Foil/15# Poly
25# MG Bl Kraft/6# Poly/.0005" Foil/15# Poly
25# MG Bl Kraft/6# Poly/.00035" Foil/15# Poly
Type I poly film - .006"
Type I poly film - .002"
25# MG Bl Kraft/10# Type III poly
25# MG Bl Kraft/10# Type I poly
6# Wax/25# Bl Cereal Glassine/6# Wax
25# MG Bl Kraft/5# Type I poly
3.5# Wax/25# Bl Cereal Glassine/3.5# Wax
1.5# Wax/25# Bl Cereal Glassine/1.5# Wax
0
1
2
3
4
Gms/100 sq.in./24 hours
100°F/95% R.H.

Fig. 1. MVT of various packaging materials

techniques can be used to advantage to promote impulse purchasing as well as identification of established lines.

In addition to its decorative properties, aluminum foil has many characteristics that make it especially suited for many applications in the packaging and industrial field. These properties are listed in Table I.

A few of these properties are best demonstrated by graphic presentation of the results of evaluations made to determine the desirability of packaging specific products in aluminum foil and comparisons of various packaging materials.

Figure 1 shows the relative MVT rates of a few packaging materials as reported to the Fourteenth Plastics-Paper Conference by Messrs. Macdonald and Downs of Thilmany Pulp and Paper Co. You will note that the three best items in this presentation and in the entire study which covered some 25 materials were foil laminated specs. The materials containing aluminum foil show extremely low MVT rates and demonstrate the fact that where near absolute protection is required, the aluminum foil specifications are most likely to succeed.

Figure 2 shows the thawing rates of 5-gal. ice cream containers. Here you can see the foil acting as an insulating material with the high reflectivity and low emissivity properties holding the temperature at a lower level for a longer period of time. The two top lines represent the difference in temperature after storage at room conditions in a control and foil laminated container as measured near the top. The bottom curves represent measurements made at the same times in the side of the container.

Figure 3 shows the per cent loss of riboflavin in Brown 'n Serve Rolls after storage in various wrapping materials. Here the foil has shielded the rolls from the degradation

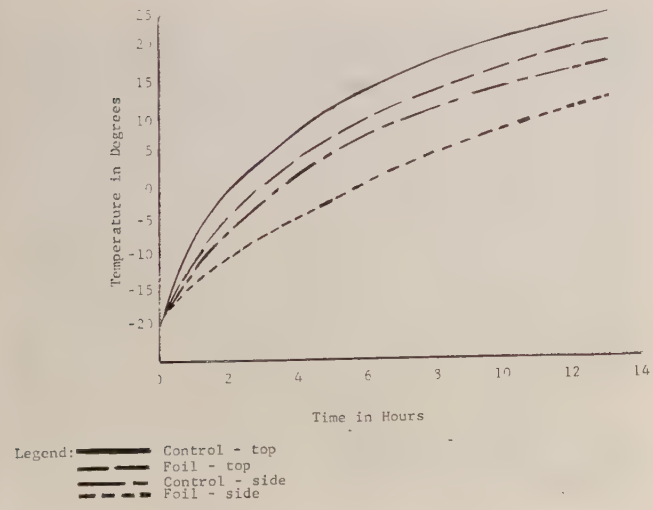


Fig. 2. Thawing rates—5-gal. ice cream containers

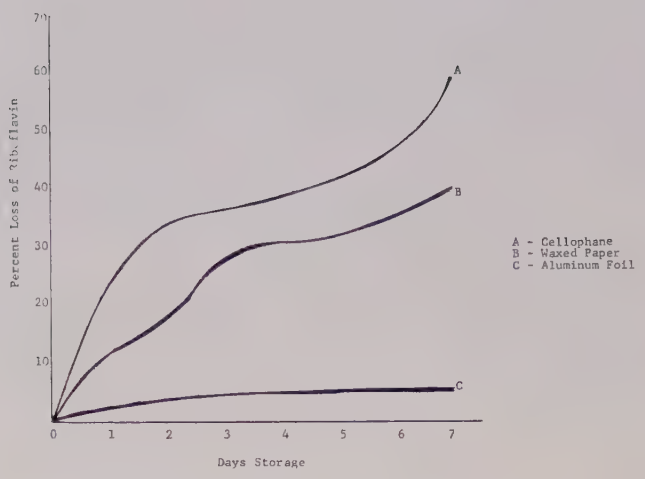


Fig. 3. Per cent loss of riboflavin in Brown 'n Serve Rolls after storage in various wrapping materials

caused by artificial light. Thus, any product that is subject to loss in flavor, vitamin content, color, etc. when exposed to light is far better packaged in a foil specification.

The practical significance of all of this to us today is that many of these properties of aluminum foil are required in order to satisfy the demands of the "convenience" food packers. The *Richmond News Leader* under a Washington, D. C., September 5, date line, quotes various experts attending the Fifth Annual Congress on Nutrition to the effect that these precooked and prepared foods have been the fastest growing category in recent years among all frozen foods and that the frozen food market will double by the mid 60's. It is also obvious that mixes are here to stay and it is reported that more are coming. In view of these facts, we believe it is safe to say that many of you will be called on to manufacture packaging materials that will have requirements best met by aluminum foil specifications and that the manufacture of foil laminating grades of paper will become routine for most of you.

In the way of developing the basic requirements of a foil laminating paper, we should consider the means of combining aluminum foil with paper. At Reynolds the combination of aluminum foil with paper and other materials is made in various ways. For the sake of this discussion and for obvious reasons we will limit our remarks to combination of foil with paper.

Probably the most common and least expensive method of combining aluminum foil and paper is to glue them together with an aqueous adhesive. There are many satisfactory adhesives available and the one used will depend upon the strength and environmental resistant properties required in the finished lamination.

In general, we find that starch, dextrin, and sodium silicate adhesives offer the lower cost. These adhesives usually have very poor moisture resistance and are suitable for specific applications where the adhesion requirements are not too great. The foil found in a cigarette package is often laminated to the paper with one of these adhesives.

Various vinyl-base adhesives are available that are satisfactory for foil laminations. These generally, but not always, have poorer water and heat resistance than are available in other types.

At Reynolds the casein-latex adhesive would probably be considered the standard laminating type. Proper formulations give high strength laminations possessing both excellent heat and water resistant properties. Since many aluminum foil-paper specifications are heat sealed and exposed to water either directly or in high moisture content atmospheres, these properties as well as the strong bond, are very desirable.

Adhesives are applied to the foil or paper and the two webs are brought into contact while the adhesive is wet.

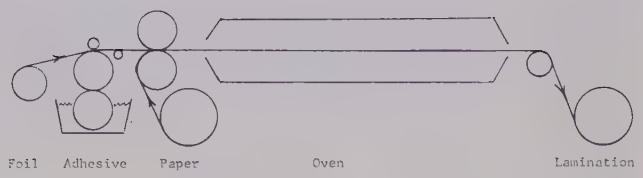


Fig. 4. Glue lamination—squeeze roll application

The adhesive may be applied by the squeeze roll or knurled roll techniques.

In general, we prefer to apply the adhesive to the metal. We find this to be the best procedure since it provides a standard surface to work against, insures the adhesive coverage of the metal, and minimizes the danger of a starved bond that can be encountered when paper absorbency, adhesive viscosity or machine conditions change. However, all of our aqueous laminations are not made in this manner, and there is no absolute rule that can be depended upon when furnishing paper for foil laminations.

In addition to glue laminating, paper is also combined with foil by means of waxes, thermoplastic adhesives, and polyethylene extrusion laminating.

Wax laminations comprise the greatest volume of these combinations. Reynolds Reyseal specifications have found wide application in overwraps and innerliners. The cereal

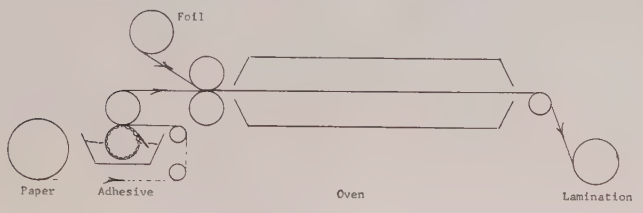


Fig. 5. Glue lamination—knurl application

liner is an example of this innerliner and our overwraps are seen on a variety to cookies, detergents, and other moisture-sensitive products.

The wax lamination may be made by application of the wax to the metal or paper, combining the webs and chilling. The techniques vary according to the wax weight desired, type of paper used, and whether or not the lamination is being made as a single operation or in-line with additional machine operations.

Thermoplastic resin laminations are fairly common in aluminum foil and paper combinations. In this case the thermoplastic material will be solvent laid on one of the webs (usually the metal), dried, and combined with the other web in a heated nip. This makes a strong bond with excellent water and chemical resistance, depending on the adhesive formulation used.

This type of lamination is used quite frequently with glassine and greaseproof papers where, because of their low vapor transmission rates, it is difficult to dry an aqueous lamination at normal operating speeds. The thermoplastic

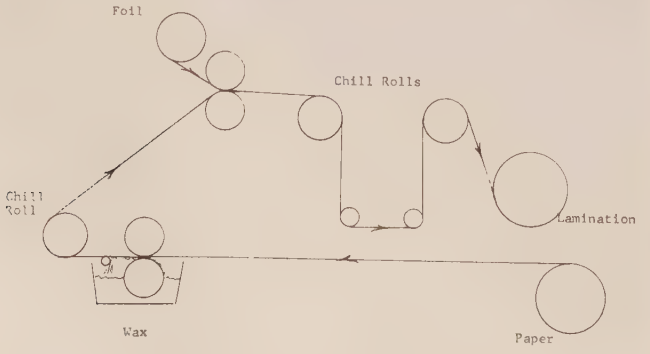


Fig. 6. Wax lamination

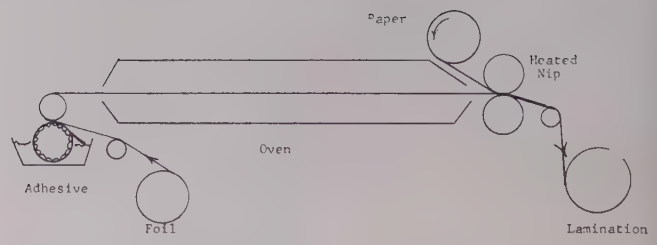


Fig. 7. Thermoplastic lamination—knurl application

lamination will also serve as a protective barrier for the metal from products that contain ingredients that are highly corrosive to it.

Polyethylene extrusion laminations are finding wide application today. The recent price reduction in the base resin, improved extruder designs and operating techniques, allowing for decreased gages, brings the extrusion lamination into a competitive range with the glue mounted specifications. In addition, this type of lamination is strong, water and chemical resistant, and the polyethylene serves as a good barrier for the metal from corrosive ingredients. We expect that this type of lamination will show very strong growth in the 60's. Figures 4 to 8 show the various laminating techniques that we have discussed in schematic form.

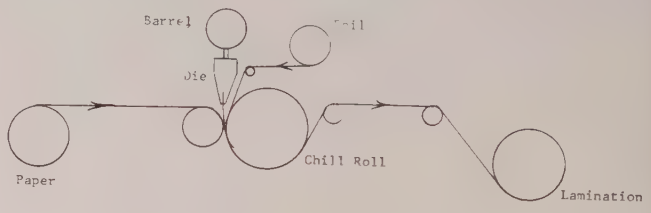


Fig. 8. Polyethylene lamination

It is readily apparent that since there are various means of laminating paper to aluminum foil, and that since there are so many possible uses for that combination, it is extremely difficult to generalize on the properties of paper needed. However, we will attempt to point out a few of the properties that appear to be most desirable and correct some of the misconceptions that we have encountered in specific instances.

First of all, concerning the aluminum foil itself, the gage most commonly used in general label and packaging work is only 0.00035 in. (3.5/10,000) thick. This is less than half as thick as many of the hairs on your head. Also, some metal is used at 0.0003 and 0.00025 in. The important point is that aluminum foil will not cover up glaring surface defects. As a matter of fact, it will probably serve only to make them

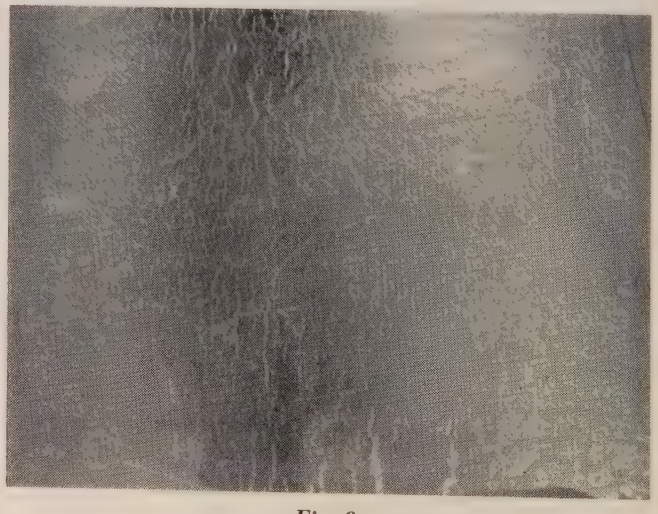


Fig. 9

Fig. 10

more obvious and, thus, more objectionable. The laminating surface color is not particularly critical since, of course, the foil is completely opaque.

As far as general glue laminating quality of the paper is concerned, a uniform, flat surface is the best. I am sorry that I cannot give you any specific expression of this characteristic in terms of some smoothness tester value. This seems to vary by grade and manufacturer. The general requirements will also vary to some extent with the thickness and sizing of the sheet, depending on the particular set of conditions. This is to say that hard sized rough boards are more difficult to laminate well under a specific set of conditions than a lightweight paper of similar qualities. As an example of this, Fig. 9 shows how bad it can be on natural kraft liner board and Fig. 10 shows how good it can be. An extremely closed and uniform surface produced this latter sample.

In addition to this smooth, uniform surface, the most important characteristic is a roll that can be unwound with a uniform pull across the width and is free of ridges, corrugations, and moisture welts. These defects make it difficult, if not impossible, to laminate and further process the stock. I am sorry to say that in spite of the continual improvement in equipment and increased emphasis on quality control by the paper manufacturer, roll condition remains a major problem from our viewpoint.

There are, of course, many specific characteristics that are requested in order to produce a finished stock that will satisfy certain demands. These characteristics are met by using papers with one or more of the properties outlined in Table II. This undoubtedly is only a partial list but it does give some idea of the various paper properties that are sometimes necessary to produce a completely satisfactory foil laminated material.

In conclusion, we hope that this discussion may have given you some idea of the nature of foil laminating and the significant contribution these laminations have made to packaging and other related fields. We also hope that this may spark some new ideas for the use of this very versatile material—aluminum foil.

Table II

1.	Wet strength
2.	Mold inhibitor added
3.	Mold free
4.	Antioxidant addition
5.	Tarnish resistant
6.	Special sizing
7.	Coated one or both sides
8.	Special wax pick requirements
9.	Flame resistant
10.	Supercalendered
11.	Machine glazed
12.	Alkali stain resistant

Presented at the meeting of the Virginia-Carolina Section of TAPPI, held in Roanoke Rapids, N. C., Sept. 30–Oct. 1, 1960.

Lake Erie

How do Paperboard Mills Maintain Uniformity?

W. O. Kroeschell

For the purposes of our discussion this evening, I'd like to define "uniformity" as the absence of "variability." Now this may seem rather obvious to you, but the importance of this statement will be seen when we realize the multitude of variables that are present in the papermaking process. I have seen any number of estimates of the number of these variables varying from 2000 to 7000. The exact number is unimportant if we realize that the figure is astronomical. The unfortunate factor is that only a small proportion of these variables are measurable, hence controllable, many more are known but still a portion of these variables are unknown. We may then paraphase the title of this discussion as "How Do Paperboard Mills Control Variability."

With the multitude of these variables, then, only with a systematic approach to their study can we take steps to control them. The first area of control in importance as well as first in the process is

RAW MATERIAL CONTROL

The raw materials for the manufacture of paperboard are wastepaper and pulp. We inspect the quality of this raw material to assure its uniformity in as many places as we can. Three points for this inspection are possible: (1) receiving, (2) loading the conveyor, and (3) as the conveyor discharges to the pulper.

We have established an inventory control program to assure uniformity of raw material among other things. One of the factors established by this program is a list of standard grades. It also establishes and details a series of inspections and tests to assure this uniformity.

The next area I would like to discuss is the measurement of the quality of the final product.

QUALITY CONTROL

The core of the quality control program is the specification sheet. This form, issued by the Technical Department, establishes the tolerances for the quality of the finished paperboard. It is the road map to guide production in the manufacturing process and it is the sign post against which the inspector performs the required tests and completes the quality record. This 24-hr. report is a record of the measurable quality.

In many cases our industry has taken further steps to establish uniformity of testing procedures through standard methods and further through industry-wide calibration as we have done with the brightness test. A successful completion of this program can only result in a greater uniformity or product from mill to mill.

To say that this program was near completion and that through these test methods we assure uniformity of product would be naive. This is the reason for the intense concentration of people in the paper industry on testing. The paperboard mills have actively supported the Paperboard Testing Committee in TAPPI. Similar work has been done by the various technical committees of the Packaging Institute.

We, ourselves, have conducted extensive research in new testing techniques to enable us to better measure the properties of our product. For example, some time ago we were not satisfied with the established techniques for measuring ply-bond strength; they weren't able to predict the perfor-

W. O. Kroeschell, Technical Director, Michigan Carton Co., Battle Creek, Mich.

mance of our board. We developed the ply-bond tensile-peel-test which used the tensile tester to measure the force necessary to peel the board apart. This was satisfactory in measuring the ply-bond strength of a given grade of board, but since it was so dependent on stiffness and stiffness is dependent on the cube of caliper, we could not readily compare different grades of board. We then looked to the end use, the forces of shear that were causing the ply-bond strength and other properties.

We have discussed how paperboard mills control variability at the beginning with raw materials and of the final product with quality control, the area in between is governed by process control.

PROCESS CONTROL

This covers a wide area. One of these areas is the measurement of the properties of the stock before it goes to the paper machine. The beater control report is an example of this. Everything is done to utilize automatic control wherever possible. Consistency regulation, stock flow control, level control, pressure control are used.

The key area in which the control variability is equipment design.

EQUIPMENT DESIGN

The average cylinder machine shows $\pm 6\%$ variability in basis weight in 4-in. intervals across the web of the machine. With the installation of the Stevens Former, this variation is reduced to less than $\pm 1\%$. Thus, tremendous strides in manufacturing uniformity can be obtained by better equipment design.

In the standard counterflow cylinder vat, the incoming stock flows over baffles and the making board. The sheet is formed on the back side of the vat and then must undergo continual washing against the flow which causes weight variation. In the Steven's Former the stock is pumped to the machine. The sheet is formed in the limited forming area between the apron and the slice lip. There is no opportunity for washing and the weight is uniform as you have seen.

To summarize then, uniformity is obtained by controlling the variability in many systematic areas: (1) raw material control, (2) quality control of finished product, (3) process controls, and (4) equipment design, and throughout all these steps, we must include constant research looking for new test methods and systems, developing new sampling methods, design of new and better equipment in an effort to control this variability and assure uniformity of our product, folding paperboard.

Presented at the meeting of the Lake Erie Section of TAPPI, held in Cleveland, Ohio, Oct. 4, 1960.

New Instruments for Process Control

R. L. Lewis

Most of us here tonight would be without livelihood were it not for some form of process control in our respective areas. Today's customer demands high production rates and uniformity impossible to attain without a high degree of in process control. We have all seen labor and raw material costs spiral upward without, in many cases, compensating relief in increased finished product prices. The resulting profit squeeze has demanded closer control of waste, elimination of marginal quality, and general tightening up in the manufacturing process. Whether we are inkmakers, adhesive suppliers, board or paper manufacturers, or boxmakers, we all have the same common problem.

I am sure I am not revealing anything you don't already know when I say that the development of improved instruments and techniques for measurement and control is taking place throughout all industry at an accelerated rate.

R. L. Lewis, Technical Director, Packaging Corp. of America, Rittman, Ohio.

So much for the broad picture. For the past several years, we at Packaging Corp., have been working on improved process control as one of our most important projects. We have developed several measuring tools of our own which have been applied to our processes with excellent results. We are participating with others having similar problems through the various technical associations such as TAPPI, BRDA. The Institute of Paper Chemistry, Intersociety Color Council, Gravure Technical Association, and others.

It seems logical to discuss the subject in two broad categories; appearance and functionability. Our ultimate customers are package users. They depend on the package to not only carry the product safely to the home, but to sell itself with attractive print copy that says "take me home." Adequate product protection and attractive appearance are obviously worthless unless the package is capable of sustained trouble-free operation on the filling line.

Any one of us can make a finished product, then do a sorting job to separate good from bad; however, this obviously is not the way to run a profitable operation. A successful operation must start with raw materials that are satisfactory and through in process checks in the converting operation prevent the manufacture of large quantities of poor quality before proper corrective action is taken. To control, we must first be able to measure, preferably without introducing the variable of human judgment. How many variables do we still trust to art rather than science? It is unfortunate that one of the mental barriers to changing all this is the recognized trait of human nature that we can do no wrong and our judgment reigns supreme.

Specifically, I think you might be interested in hearing of our experiences with several instruments which have helped put numerical values on those characteristics that previously required human judgment or more costly wasteful actual running experience to evaluate.

You have already heard in previous talks about some of the controls used in paperboard manufacture to assure proper quality levels. I would like to get into more detail on some of those that are relatively new.

Let's take appearance characteristics first. More and more emphasis is being placed on color, shade, and brightness because of the increased use of copy with more white area and photographic reproduction. It is no longer adequate to make broad shade matches by eye even though the eye is still the most sensitive though somewhat inconsistent color measuring device.

We use two tristimulus colorimeters, the Colormaster and the Color Eye. Both instruments measure the reflectance of the sample to three known filtered bands of colored light against a permanent standard. Both have stable electronic circuits requiring no special voltage regulators and are rugged enough to be used under actual production conditions. The reflectance values can be readily converted to universally accepted color coordinates. In actual use we graph McAdams coordinates as the board is being manufactured (a values: red-green, b values: yellow-blue). Tolerances are shown on the graph by a circular area, the midpoint of which is the standard. Values are separately plotted to show lightness-dullness (L or G). The plot not only tells our operating people where they are in relation to the standard but shows the direction necessary for corrective action. The proof of the pudding is a drastic reduction in off shade board costing many thousands of waste dollars or dissatisfied customers for an expenditure of $2000 to $3000. Our experience may be unique; however, we feel, and this opinion is shared by our operating people, that we could not continue to manufacture to today's requirements without this equipment.

These instruments are useful not only to measure and control board shade, but are finding increased use in control during multicolor printing, particularly offset printing where more color variation is inherent.

Most of us here are interested in the evaluation of print-

ability. The place to determine this is at the end of the paper or board machine, not on the press.

For the past five years we have been using numerically graded proof samples made during the board run as guides for the machine operating people. The system uses a 219 Vandercook press with a graduated makeready. A standard ink film is applied. Good printability is the sheet that will print satisfactorily on both solids and halftones with minimum impression. We are currently evaluating in our laboratory a bench model printability tester developed by the BRDA End Use and Physical Test Committee incorporating these same principles.

Because of the basic differences between letterpress and gravure, we also use a Diamond-National gravure proof press to refine our printability evaluation of board for gravure printing. The number of missing dots per unit area can be readily determined as the numerical value. We are aware of a further refinement for counting missing dots using a scanning device coupled with an electronic counter.

Another extremely valuable tool for predicting satisfactory multicolor printing at the end of the board machine is the IGT pick tester. The tester applies a tack graded ink film at an accelerating velocity of 0 to 600 f.p.m. which covers most commercial press printing speeds. The end point is the speed in feet per minute passed without surface rupture.

The ideal process control instrument duplicates in the lab those forces which the product must withstand in actual use. This may include conversion into finished product as well as actual end use. Those of you who make inks know that excessive scuff and rub is not acceptable to our customers.

The conventional rub testers do not always go far enough to properly evaluate the suitability of the finished printed package. A realistic evaluation of possible ink film breakdown can be made on filled packages in the shipping case on an LAB shake tester. The tester provides as an example, in 1 hr., combined vibrating and rotating action which has been correlated to what can be expected during truck shipments of about 1500 miles.

As filling line speeds have been stepped up the forces necessary to erect a folding carton and the forces necessary to close flaps have become more critical. Fight or variation in these forces can cause jam ups, readjustments to filling equipment, etc.

Several years ago we developed a score bend tester which combines these force measurements. Flap score stiffness which is affected by scoring makeready, board stiffness, etc. are constantly monitored during carton conversion. Opening force which is governed by prebreak and ironing on a gluer are likewise monitored. Standards established as a result of correlation with the customer's filling line requirements have resulted in improved performance. We are making this instrument available commercially to others who may wish to use it.

We would be remiss if we didn't gaze into the crystal ball a little to say that many of the present measurements will progress from the bench to an on machine status. Important to all of us as a classic example is moisture control. A lot of effort is being expended to find better measuring techniques that can be made to work on the machine. Continuous monitoring of basis weight, caliper, and moisture is just around the corner. Continuous brightness measurement and control is already being accomplished. A satisfactory test for glueability is now being investigated by the BRDA group and others.

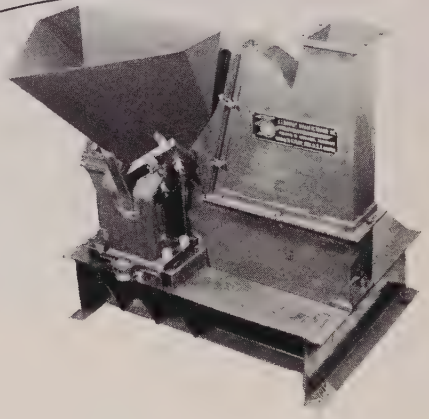
Our industry has been accused of being slow to turn art into science. It behooves all of us to make as great a contribution as we can to general industry process control development programs. The economic health of our industry is at stake. We feel that improved process control will make a major contribution to keeping our heads above water.

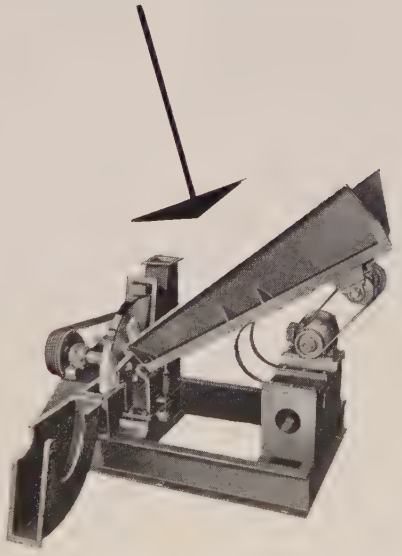
Presented at the meeting of the Lake Erie Section of TAPPI, held in Cleveland, Ohio, Nov. 3, 1960.

Reclaim OVERSIZE CHIPS

Murco Rechippers

REAL MONEY SAVING EQUIPMENT FOR MILL OPERATORS LOOKING FOR QUALITY & QUANTITY IN CHIP PRODUCTION





Capacity 400 to 500 cubic feet per hour with ½" chips and vibrating feeder.

MURCO 40" 6 KNIFE LEFT HAND RECHIPPER WITH STATIONARY SPOUT.

CAPACITY 700-800 cubic feet of chips per hour.
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THIRD ANNUAL RESEARCH CONFERENCE

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and

Technical Association of the Pulp and Paper Industry

NORTHAMPTON, MASS., NOV. 4–5, 1960

Research and the Paper Industry

WARD D. HARRISON

It is indeed a real pleasure and an honor to be here today and to address this Third Annual "Research Conference." I had the privilege of attending the first conference held in Highland Park, Ill., two years ago and I was deeply impressed by the serious way in which the delegates there went about their work. I note from the program that you, too, will have a busy time of it and I would like to congratulate the men who have prepared this program for you.

The composition of this group is a most interesting one, half of you are from the academic field and half from the paper industry. It is true that both groups are bound together by intellectual curiosity and an interest in science.

I cannot help but feel that we are bound together in other ways as well. We all are users of paper. When we were born, our birth certificates were made of paper. We all read newspapers. We all dry our hands with paper towels. We all eat from paper plates. A good many of us smoke cigarette paper. We send and receive letters, bills, postcards, and advertising all made of paper. And in just 6 weeks, we will begin to receive an avalanche of greetings made of paper. Our supplies—our food—yes, almost everything is packaged either in a paper box, carton, or bag. When we were married, our marriage licenses were of paper. We earn and spend paper money and when we die, someone will file a death certificate made of paper, too. I also note in the October 24th issue of the *U. S. News and World Report* where the president of one of our famous universities was quoted as saying that his three most critical problems were (1) salaries for professors, (2) football for alumni, and (3) parking for students. This is similar to what confronts a paper corporation president today. Three great problems for them are (1) salaries for technically trained people in order to make sure we get and keep our fair share, (2) profits for stockholders, and (3) quality and service for our customers.

Some of you are not as familiar with the paper industry as those of us who work in it. Therefore, I would like to give you some important background on what our industry is and where it is headed. Of course, I think it is one of the greatest industries and is headed for even greater accomplishments in the future. Before we get into the future, however, let's get the backdrop of the past. It is interesting to remember that, of the ancient peoples, the Chinese of more than 2000 years ago were in a relatively high degree of civilization. They were the first to manufacture paper. Their civilization faded as they failed to develop the art of papermaking and its use. We have not failed in this respect, we have come a long way. We have developed papermaking almost to a science and we have put the product to use. Paper production can be used as an index of civilization and we in the United States have a high ratio of paper usage per capita. Since I have been in the paper industry just a little over 25 years, let's consider what has been going on in our industry during that time.

A quarter of a century ago, the United States was just then coming out of a great depression. Jobs were scarce, and our industry was running at low ebb. The manufacture of pulp and paper, to a large extent, was still veiled in a certain mystery, using secret formulas and magic processes. Rule-of-thumb was the order of the day, and the technical man was barely accepted. The forests of the Northwest and of the South had scarcely been tapped for our use; hardwood was a drug on the market; investment people looked with a jaundiced eye on the pulp and paper business—some of our large companies even refused to allow their men to join the Technical Association of the Pulp and Paper Industry or to attend its meetings. Other associations, like the superintendent's association (now called Paper Industries Management Association) were in the same boat.

Let me contrast for you the situation as it exists today. We are producing over three times as much paper and consuming almost $2^1/_2$ times as much per capita. We are drawing heavily on the extensive timber resources of the Northwest and the South; we are utilizing our hardwoods and the scrap from our sawmills; as a matter of fact, I don't know how we would

Ward D. Harrison, President, Allied Paper Corp., Kalamazoo, Mich.

get along without hardwood today. We are growing trees faster than we are consuming them; we are also using more wastepaper than ever before; we are producing a multitude of new grades of pulp and paper; and now, the stature and stability of our industry have increased so much that investment people look on us with great favor.

In the *Reader's Digest* a few years ago, a number of new uses for paper were listed. For example, it reported, "During World War II, the paper industry presented the Army with a map paper so strong that even when soaking wet, it could be run over by a tank or trampled by a combat-booted regiment with no noticeable effect." That "wet-strength" paper and, yes, the "wet-strength" paper developed even before that by one of our delegates, Ken Britt of Scott Paper, was the beginning of a whole new era in papermaking. Paper is no longer just paper. It teams up with chemicals, plastics, rubber, and glass to do some almost incredible things.

"Today, with paper, you can build a snow fence or upholster your furniture. You can swim in a paper bathing suit. You can paper your rooms with wallpaper that will paste itself, kill flies, and still at the same time repel dirt; you also can carpet your kitchen floor with vinyl-coated paper flooring that looks like linoleum and is said to wear longer."

I could mention more examples like nonrattling popcorn bags for theaters, laundry tags that will withstand ten washings without noticeable wear, paper filter bags of controlled porosity for vacuum cleaners, and even a resin-impregnated paper which can be pressed in a manner so as to be used as a printing plate, to say nothing of the sanitary products and paper clothing now available.

Now, it would be unwise, if not dangerous, for us to claim too much credit for technical men in all these developments. Yet, I would call your attention that an industry that dates back to antiquity has, in the past 25 years, taken on new life. I think this has come about to a large extent through the substitution of fact for fiction; by the creative efforts of the research man in developing new and better products; by use of the technical man who investigates materials and controls operations; by the labors of the engineer who measures, calculates, designs, and builds new instruments, machines, and facilities; and last but not least, *by the leadership* of the well trained superintendent and supervisor who guides the line organization through their daily routine with a minimum of down time and grievance, and a maximum of efficiency, production, and quality.

Let me point out further that both TAPPI and the American Paper and Pulp Association (the sponsors of this meeting) have been an energizing and coordinating force in all this transformation. The TAPPI organization has accumulated and disseminated a vast amount of information. Standards of testing have been set up and are used in a large measure the world over. TAPPI divisions and committees have served the industry through publications, meetings, and conferences to say nothing of the research they have sponsored. TAPPI research grants have averaged about $75,000 per year for the last 5 years with a high of $100,000 in 1957. Supported projects may take such widely diverse forms as basic research, literature review, or the development of testing procedures. This work has almost entirely been carried on in universities and colleges.

And, what I say of TAPPI in a technical sense is likewise true of the American Paper and Pulp Association in the field of management. But the American Paper and Pulp Association has been interested in research, too, and has been spending money in the interest of it. Their Committee on Coordination of Research came out 2 years ago with a list of some of the more important fundamental research problems of our industry. The objective was to recognize many of the unanswered questions in the physical and biological sciences which have an important relationship to the numerous facets of the pulp and paper industry, and to assemble them according to area of science in a manner which will be meaningful to research organizations and particularly to the many educational institutions capable of conducting studies in these fields.

The benefits and accomplishments of associations like TAPPI and the American Paper and Pulp Association have undoubtedly helped provide the stimulus for further development and growth in the paper industry.

Dr. Nethercut, executive secretary of TAPPI, in a discussion of growth in the paper industry has said, "The general public is well aware of the rapid growth of some of our country's more captivating and glamorous industries. Relative to these, however, the paper industry is assumed to be static, if not stagnant. This misconception is a damaging one, particularly among young people who thereby underestimate the opportunities for personal advancement in the industry."

Cola Parker has said, "The paper industry has a fabulous record of growth behind it and an almost unlimited growth potential. Few industries with histories as long can boast a rate of growth as robust in terms of tonnage production and consumption of products."

I have already told you that our growth in the past 25 years has been threefold. However, in the past 50 years, pulp and paper production has multiplied ten- to twelvefold, although the population has only doubled. Wheat production has risen only about 70% during that period, and cotton production has actually declined. Even finished rolled products of the total steel industry have increased only six times.

Per capita consumption has increased more than five times in the past half century and no end is in sight. Predictions, based on population estimates, with new products and new uses being constantly developed, indicate that paper and paperboard production will increase by anywhere from 60 to 100% within the next 25 years.

We in the paper industry could not have expanded to meet such growth had we not found the solution to some basic technical problems such as: (1) pulping new species of wood and at higher yields, (2) using chemicals to impart new properties to paper products, (3) building faster paper and converting machines, and (4) developing stronger and more perfect paper to run on these new high-speed converting machines and printing presses, just to name a few.

But what about the future? At the present time, our industry is overexpanded so productivity is no problem at the moment. This situation however, will not last long if our traditional growth pattern is followed. Quality, however, is a problem and has been for a long time. Take wood as an example. If we could breed better species of trees through research in genetics, we could have better fibers with which to work. If we could pulp the variously sized fibers of varying chemical composition selectively, we could produce a better pulp than the average pulp we now get with our old processes. If we could form paper better from the fiber-water suspensions, we could produce still better papers.

Why haven't we been able to accomplish these goals? Dr. Whitney, in summing up a panel discussion at The Institute of Paper Chemistry in 1959 on this subject said, "The answer is clear; it is our ignorance—our lack of understanding. Whether it is the kinetics of a delignifying reaction, the hydrodynamics of a slurry system, the chemical structure of a lignin, or energy sites on a cellulose fiber surface, the conclusion is the same. We must have more knowledge and more understanding of fundamental properties and behaviors. The industry and its associated organizations have done a fine job in applied research and development, in application and translation. There has been some excellent fundamental research as well, but there has not been enough of the latter to keep pace. We have depleted the backlog of our basic understanding. Significant progress in the future will be more than ever dependent on a sustained and substantial volume of competent, long-range, pioneering research."

So, there you have it. The paper industry is hungry for new basic understandings. In addition, we need ever-increasing numbers of scientifically trained personnel. We are no different in these respects from the many other industries that are based on scientific knowledge. But we are in competition with these other industries for university research time and scientifically trained men from universities. It is no secret that we in the paper industry are anxious to have you in the academic field know our problems better. We are interested in the research you do and the men you train. This makes you a very important part of our industry.

If I were a professor I would not want to miss the opportunities for research in the paper industry.

If I were a student I would not want to miss knowing about a fascinating industry like ours.

Where will you find anything as versatile as paper? Thick or thin, light or heavy, flexible or stiff, tough or fragile, plain or colored, large or small. Its applications are limited only by man's ingenuity.

Paper remains the lowest-cost, mass-produced, flexible sheet available and the industry is learning how to build almost every conceivable property into it. It's interesting—it's exciting—it's rewarding—and I can recommend our industry to each and every one of you.

Presented at the APPA-TAPPI Research Conference, held in Northampton, Mass., Nov. 4–5, 1960.

Technology and Growth

LOUIS H. RODDIS, JR.

It is a great privilege to be present at this meeting with so many persons interested in technological activities. As one whose acquaintance with paper has been confined generally to the type used for newspapers, textbooks, and an unending stream of interoffice memos, I was surprised to learn that the American Paper and Pulp Association has 13 divisions representing manufacturers of distinctively different paper products.

However, I have a very vivid recollection of just how important paper can be, which stems back to Dec. 7, 1941. I was on a battleship at Pearl Harbor when a bomb destroyed the paper storage room leaving us without mimeograph paper, towels, and toilet paper. And you can take my word for it, the shortage of these items caused more griping than the Jap bombs.

As one who has had considerable association with research and development activity through work in the atomic and electrical fields, I am amazed at the extent of the R and D work sponsored by your associations. In looking over the report on research projects sent to me by Doc Plummer, I noticed that 74 colleges and 15 governmental and private organizations are engaged in one or more of the 811 projects listed in the report's index. In the interest of scientific accuracy, I would like to add that the 811 covers only the main subjects, and not subsubjects such as the 29 under "pine" of which one subsubject, "loblolly," has an additional 17 subsubjects.

For me to even attempt to discuss technological activities in a field of this scope with men who are much more learned in it, would put me in the class of a hunting dog about which Dwight D. Eisenhower spoke at a recent symposium on basic research.

A guide in the north woods, who had long enjoyed a warm acquaintanceship with a university community, had the habit of naming his hunting dogs for faculty members whom he admired. But when a few wives became indignant over the practice, he decided to name his dogs for various academic ranks—instructor, assistant, professor, and so on.

One season a man from Boston hired for $2 a day, a dog he liked very much. The following year, when he asked for the same dog, he was told the price would be $5. When he protested the steep inflation and insisted that it was the same dog, the owner agreed but said the dog had been promoted to assistant professor and now was worth more money. The next hunting season, the price jumped to $7.50 because the dog had

Louis H. Roddis, Jr., President, Pennsylvania Electric Co., Johnstown, Pa.

achieved the rank of associate professor, and the year after it, the price was raised to $10—the reason being the well-trained canine had reached the noble status of full professor.

The following year when the hunter returned to rent the same dog, he was turned down. To his demand for the reason, the guide replied, "Well, I'll tell you. This spring we gave him another promotion and made him president of the college. Now all he does is sit around and howl, and he isn't even worth shooting."

Now, even though my knowledge of papermaking is limited, there may be some usefulness in considering a common interest—the contribution being made by scientific activities, such as you men are making in the paper industry, to the growth of this country and to creating better living conditions everywhere.

All of you here are as cognizant as I of the scientific and technological explosion which is revolutionizing our lives. It is re-arranging the patterns of our domestic life, it is changing the way we spend our dollars, it is reshaping our communities, it is changing the form and function of our factories and offices, it is making work less arduous and life more comfortable and convenient.

Approximately 60% of manufactured products being marketed today were either unheard of or were only in the creative stage 20 years ago. The utilization of plastics for a wide variety of building purposes, the use of synthetic fibers in clothing, the development of nuclear power, and the growing achievements of isotopes in agriculture and medicine are only a few of the examples of the increasing importance of man-made resources in this technological age.

In the past few years, man has made such a "quantum" advance in technology that it is difficult to fully visualize the full impact of changes made in the present "man-span." This was brought home to me rather forcefully earlier in the week while reading Walter Lord's book, "The Good Years." Under the title, "The Whopper Flying Machine," Lord told how, after flying a plane 852 ft. in 59 sec. at Kitty Hawk, the Wright brothers turned to the pleasant task of informing the world of their triumph. Their hometown paper in Dayton refused the story and only the editor of the *Norfolk Virginian-Pilot* realized the importance of the story which he tried to sell and had only five takers. One of them, the *New York Tribune*, carried the item on the sports page, underneath an account of a sandlot football game.

Aeronautical experts, like newspaper editors, could see little commercial future in the flying machine and in 1911 W. B. Kaempffert, a recognized authority, said the airplane would never have any use in war because, "every small boy knows how hard it is to drop a snowball on someone from a third story window."

Yet only 34 years after those words were uttered, a B-29 dropped an atomic bomb on Hiroshima and hastened the end of World War II. And in that period the airplane along with the automobile, also little more than a curiosity at that time, have revolutionized transportation.

Lord also wrote, "a steady stream of things is enriching the life of everyone—the safety razor, the perpetual pencil, the long-distance telephone, the talking machine, and house cleaning by the pneumatic process to name a few." Two of the biggest attactions at the St. Louis Exposition were a ferris wheel and a paper-box factory in full operation.

To more quickly grasp the enormity of technological growth, let us break up time into "man-spans" based on the Biblical three-score and ten years. Most of what we know today has been learned in less than 100 "man-spans." The steam engine, key to the Industrial Revolution, came into being less than three "man-spans" ago; and it is only one "man-span" since Edison put electricity to a practical use. It is fantastic the growth made in industrial arts and the fields of manufacturing and production in one-third of a "man-span." For instance, in the electrical field in 1940, there were only 13 devices made for use in the home, while now there are 69 available. They not only serve the modern housewife better than the Queen of England is served by the 233 servants in Buckingham Palace, but they are available at a cost just about every housewife—at least in this country—can afford due to automated production lines.

These production lines are becoming more automatic every day. Almost too recent to be measured by a "man-span" is the development of servomechanisms which enable machines, built largely of cheap electronic parts, to examine their own work and to improve their output.

Scarcely had man begun to exploit the feedback loop principle then the electronic computer appeared. This performs thousands of operations per minute with high reliability and can carry within its memory an almost endlessly long and complex sequence of operations. It can be used to control a variety of other machines including one which can make a prototype.

Of the 1100 machine tools and related items at the Production Engineering Show and Machine Tool Exposition in September, 85% had some form of automated control. Claims as to how many workers could be eliminated and how many times production could be increased by these machines ranged up to that of a manufacturer of textile machinery who asserted his machine would increase production 50-fold.

Given its first national outing was a system of numerical controls which, unlike the so-called automatic controls in use, do not require cams, templates, masters, limit stops, metered hydraulic systems, or similar devices. Once instructions are put on tape, machines can be changed from one type of operation to another with relatively little expense.

The list of strange and revolutionary devices entering our lives in a virtual unending stream, could be extended greatly, but little would be accomplished other than to prove to you, who need no proof, that our expenditures of between 5 and 6 billions of dollars per year on research and development is worthwhile.

Instead, I would like to do a bit of philosophical research into the question of whether or not man's technological growth is rapidly outstriping his capacity to control it.

In all fields of human endeavor today, we are involved in a tug-of-war between immense forces which are pulling groups, nations, and races apart. It is ironic that in this time of lightning-swift universal communication, we are threatened with massive defaults in understanding. In education, politics, so-

ciology, and the arts, we are approaching a modern Tower of Babel.

Perhaps we need a new look at the activities of man surveyed as an organism. Perhaps we need a new breed of specialists who will devote themselves to seeking out more effective methods of integrating the knowledge and the work of the physical scientist, the engineer, the humanist, and other professional disciplines.

There must be a better way to harness the human imagination and spirit unlocked by our technological developments than to have 5% of our labor force unemployed and to have hunger among two-thirds of the people of the world.

Is our only answer to technological unemployment the 32-hr. week and if so, what can be done to keep contented, an individual who will be producing less than 20% of his time?

Are the clamors of millions of people throughout the world for a better way of life to be met by that which has been the last arbiter of disputes throughout history—namely war? Cannot the same system which split the atom, developed jet planes, and made color television a reality, find ways to develop worldwide brotherhood?

I ask these questions not so much in the hope of obtaining an answer here tonight, but rather to dramatize the fact that technological growth has created problems far in excess of those associated with transferring the ideas of the laboratory to a practical and economical product. History indicates that it took 100 years for benefits of the Industrial Revolution to spread much beyond the shores of the British Isles. Today, thanks to improved methods of communication, significant scientific advances are known around the world literally within hours, stimulating a demand for the product long before capacity to produce, or even use it, is available.

Only four "man-spans" ago, the time for any important achievement was marked in years, and ideas were spread mainly by sailing vessels looking for spices and furs. With the steam engine, the week became important as a measurement of time. Within our "man-span," the airplane made the day significant and we had little time to adjust to this until other technological developments shrank the time scale closer to its ultimate limit—NOW.

Hundreds of millions of people are clamoring for a better way of life NOW. While here in America we wrestle with turret presses capable of drilling 1920 holes per min., all people in many other lands want is sufficient equipment to produce TV sets, refrigerators, and pink toilet paper. This, in spite of the fact they haven't fully mastered use of the lever and wheel. Probably as good an example as any of this overstimulated desire comes from the Congo where tribal soldiers are still fighting with spears in an attempt to progress over night as far as this country moved in 184 years.

The intense nationalism, impatience, and frustration of so-called backward nations have been intensified greatly by the technological revolution and further complications have been added by an "exploding population." The world population at this moment is exploding at the rate of about two and one-half times per "man-span" and the rate is accelerating. Rapid increase in population imposes a severe burden on efforts to raise levels of living, especially in economically underdeveloped areas. For example Asia, merely to maintain her present low level of living must increase her aggregate product by 60% until 1975 and by an additional 75% between 1975 and 2000. Africa, to increase her per capita income to the European level for 1950 would have to increase her aggregate income of that year 12-fold by 1975 and 21-fold by 2000.

The rate of the world's population growth has been reconstructed by demographers with what is regarded as reasonable accuracy. According to Professor Philip M. Hauser, head of the department of sociology at the University of Chicago, the world's population at the beginning of the Christian Era was 200 to 300 million and in 1650 it was 500 million. Today it is approaching three billion. The rate of growth has increased from 0.3% to more than 2% per year.

Changing to our "man-span" method of computation to dramatize the time period, we find that the world population is exploding at the rate of two and one-half times per span. It doubled once in the previous life span and now is heading toward what is believed to be the ultimate—a four to sevenfold increase per "man-span," depending upon ethnic group.

It is doubtful whether our world can long support this kind of growth without significant economical advances or a change in the birth and death rates. Records indicate that death plays a more vital part in population growth than birth. For instance, Ceylon's population growth zoomed from two to fivefold per "man-span" simply because the death rate was cut in half in 7 years through the use of DDT—one of our modern technological achievements.

If the present rate of population growth continues—remembering that every 9 months it is applied to an ever increasing base number, within six "man-spans" there will be 50,000 persons for each one now alive and there will be only 1 sq. yd. of land—including deserts, mountains, and icecaps—for each individual.

Dying may or may not be increased in the meantime by natural disasters and pestilence, but these events are becoming rarer. War is becoming an increasingly more efficient killer and may solve the problem, but we hope it doesn't. And, of course, all calculations could be upset by today's big killer—the automobile. I'm not sure whether technology accounts for a gain or loss in this category.

Numbers do not necessarily guarantee prosperity as it should now be clear to the many economists who predicted a golden era for the "Sixties" based on the large number of war babies who would reach the marriage age in this decade and would keep factories humming to satisfy their demands for homes and furnishings. If numbers produced prosperity, India would be one of the most prosperous countries in the world.

A recent report by the United Nations, based on 1950 statistics, stated that North America with 16% of the earth's surface, had less than 9% of the population but about 43% of the earth's income. Asia, with 18% of the surface, had 55% of the world's population only 12% of its income.

"The major factor underlying this difference," the report continued, "is indicated by the difference

in the energy consumed. It is more than 10,000 kw. per capita in North America and less than 300 kw. in Asia. The availability of nonhuman energy for the production of goods and services is perhaps the best single measure of difference in capital investment, know-how and technology which account for the great differences in productivity and, consequently the size of the aggregate product available for distribution."

In view of the situation, what responsibility does the scientist have to society?

Does development of new techniques to relieve suffering by the conquest of disease carry the responsibility to alleviate the sufferings caused by overpopulation?

Does the development of new and stronger weapons obligate one to create a new comradeship among nations?

The possibility that the answers should be affirmative, is indicated in Professor P. W. Bridgman's research discussion, "Some of the Broader Implications of Science" in which he comments": "The fundamental ideological problem which confronts us all, is of finding intellectually satisfactory methods of dealing with the world around us. The traditional methods of attack on this problem in the past have not involved the scientist in any considerable extent but have rather been the concern of the philosopher."

Roger Bacon, with his deep insight into the meaning of science and technology for civilization nine "manspans" ago, wrote: "But above all, if a man could succeed not in striking out some particular invention, however useful, but in kindling a light in nature—that man would be the benefactor indeed of the human race, the propagator of man's empire over the universe, the champion of liberty, the conqueror and subdoer of necessities."

In America, at least, Bacon's admonitions became lost in a century and a half of pragmatism, born of the immediate necessity of developing and harnessing our natural resources. We have been clever and energetic about exploiting new knowledge and new ideas in the physical science. Indeed it has been this ability which brought world leadership to the United States. There would be a lot less danger of our losing this leadership if this same cleverness and energy were applied to research in psychology and the life sciences.

I would like to stress that any statements I have made or will make later should not be construed as criticizing the amount or character of the basic and applied research being done by our universities, the government, and private enterprise. Every bit of it is worth while and should be expanded.

Rather my theme tonight is that the growth achieved in technology must be extended to other humanities and that such extension can best be obtained by use of techniques developed by the basic research scientist.

It is foolish conceit to believe that step-by-step charting of a course into the unknown can be done or that a satisfactory solution will follow the stating of a problem. Here, the general philosophy advanced by Professor John von Neumann a few years ago, shows what can be gained from appreciation of theory. This is by involving what he called teleological research, and is illustrated particularly by alternate concepts of classical mechanics. Thus, instead of defining a state by every single step, by every single velocity of every single part at every moment, one thinks of defining its actual history by minimizing the integral of energy times time. There is bold import for much modern research in such alternatives.

We have the opportunity to treat our technology as a means to an end, to use it to build a humane civilization that is concerned with the quality of human life as well as the quantity of material goods; a civilization that can provide its citizens with opportunities to think, to enjoy and to contribute to a better life.

Life today has had its cognitive basis weakened because it is confronted with situations in many ways so different from those for which its institutions were created. Events occur with more rapidity and variety. Public life is more vast and its interconnections are more numerous, more swift, more subtle, and less understood than in any other age.

If we do not use all of our skills to solve the problems of the exploding population, of supplying full employment to all of our people and to still the world's growing unrest, our tremendous technological growth will become futile and meaningless.

Let us continue our research and development into semiconductors, solid state physics, molecular weight, isotopes and the heritability of tracheid wall thickness of loblolly pine but at the same time let us work a bit harder to develop a unifying theory to advance our understanding of sociological events and to create a better and happier world.

Presented at the APPA-TAPPI Research Conference, held in Northampton, Mass., Nov. 4–5, 1960.

Science of Wood Pulping

G. H. TOMLINSON II

THE objective, in a scientific study of the production of wood pulp, is to establish the underlying principles involved in this technological field. In spite of a history of over 100 years of pulp production we have moved only part way along this road. I need hardly mention to this particular group that pulp research today is still remarkably rewarding, no doubt because we are building on an expanding and as yet not totally explained body of knowledge.

George Thomson, president of the British Association for the Advancement of Science, has recently stated (*1*) that "the best way to make advances in technology turns out to be to understand the principles. This is quite a recent discovery; indeed it has only recently become true." He also points out that in

G. H. TOMLINSON II, Research Director, Howard Smith Paper Mills, Ltd., Cornwall, Ont.

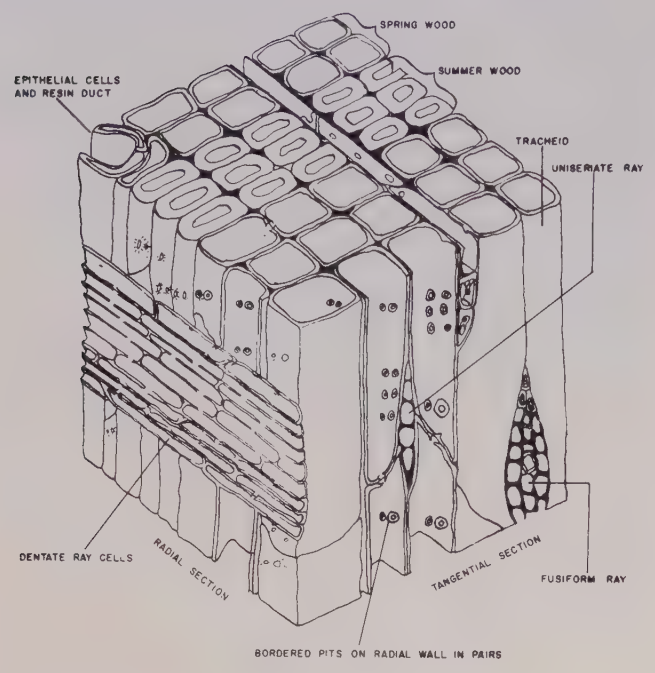

Fig. 1

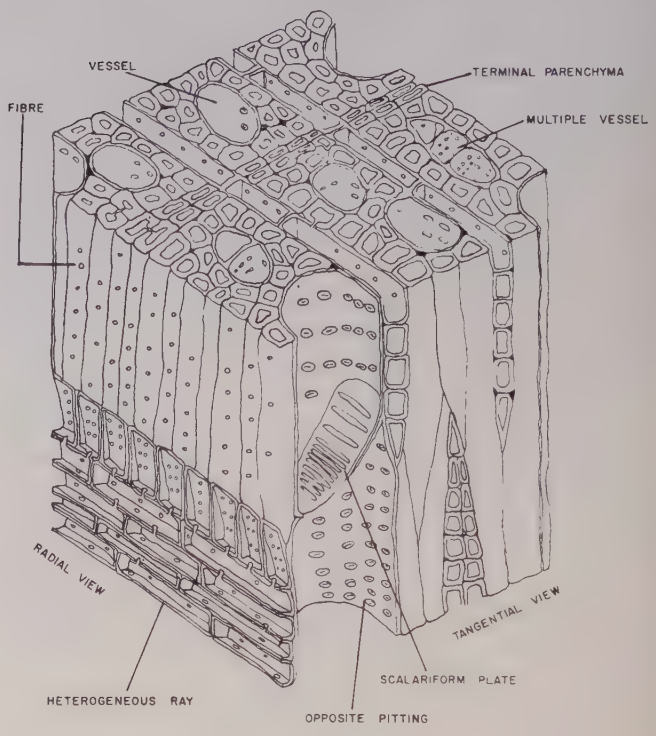

Fig. 2

establishing such principles, which makes the pursuit of science so fascinating and worth while, we must start "by studying detail, often apparently trivial detail, of things that are queer and appeal to human curiosity."

Thus in developing our topic today I hope you will excuse me if, instead of outlining the broad principles which you no doubt expected to hear, I start with detail, some of it apparently trivial and queer.

THE STRUCTURE OF WOOD

Our raw material, wood, is a highly specialized biological product. Wood from one tree is never identical in all respects with that from another nor in fact is it identical from different locations in the same tree. Nevertheless, there are certain broad features common to woods of similar species which fact allows us to generalize. Wood is a porous material which in the case of coniferous woods largely consists of interconnecting fibers or tracheids oriented in the longitudinal direction of the tree. These fibers provide the main strength to support the crown of the tree and act as channels for conduction of sap and water between the roots and the leaves. Figure 1, an enlarged diagram of a block of short leaf pine, shows the tracheids oriented in a vertical direction, thin walled in the springwood which is formed during the period of rapid growth, thick walled in the summerwood. The ray cells running in the radial direction of the trunk and at right angles to the tracheids act as a reservoir for carbohydrate and other food material. So-called epithelial cells surround the resin duct. In hardwoods the tracheid fibers play only a minor roll in the vertical distribution of sap, the vessels having this function. These can be seen in Fig. 2, an enlarged diagram of a block of tulip poplar.

In the coniferous woods the tracheids occupy 89 to 94% of the volume, the ray cells about 5 to 11%, and the resin cells about 0.2 to 0.8%. In the hardwoods the fiber volume is of the order of 36 to 70%, vessel volume 20 to 55% and ray volume 6 to 18%. The bark contains bast cells, thin walled phloem-parenchyma, and phloem ray cells.

THE CHEMICAL COMPONENTS OF WOOD

Figure 3 illustrates the chemical components of wood. From the analytical standpoint, wood is normally fractionated into three main categories; holocellulose, lignin, and extractives. The holocellulose is further fractionated into the alkali insoluble alpha-cellulose and the alkali soluble hemicellulose. The alpha-cellulose contains not only the true cellulose, a 1-4 anhydro glucose polymer but also xylan, mannan, and galactan polymers built up from the anhydrides of xylose, mannose, galactose, etc. Glucomannan, an important cellusan of softwoods, is a mixed

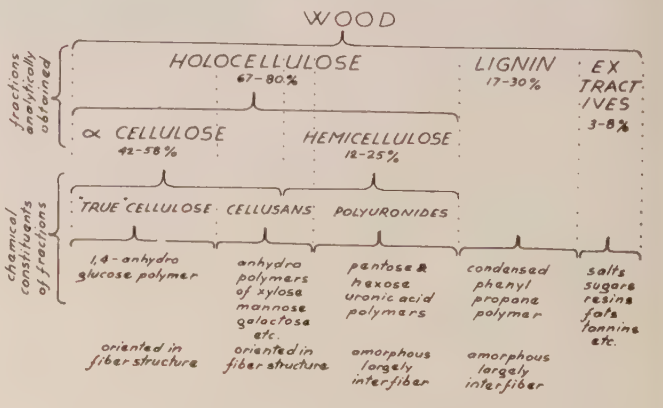

Fig. 3

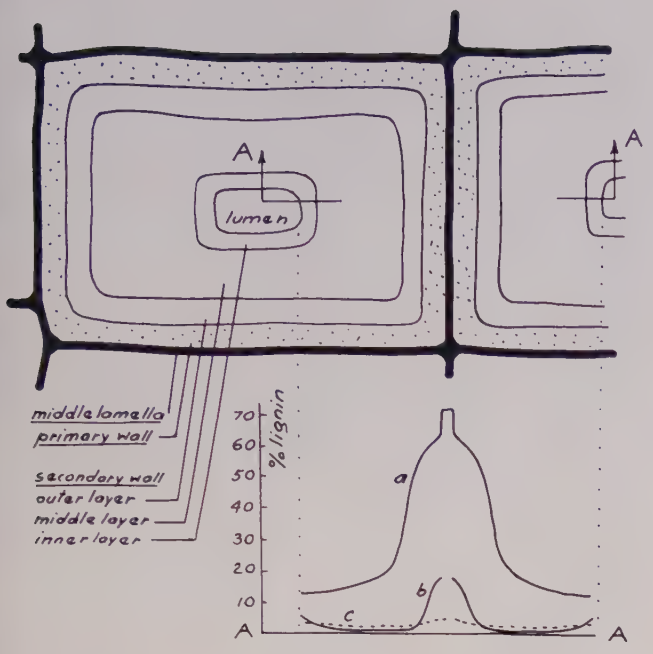

Fig. 4

polymer of glucose and mannose anhydrides. A portion of the cellusan, but probably of lower molecular weight, is also found in the hemicellulose material. The polyuronides, the principal hemicellulosic material, are also polymers, the chief ones being 4-O-methylglucurono-xylan in hardwoods and 4-O-methylglucurono-araboxylan in softwoods. These products are characterized by the carboxylic acid grouping of 4-O-methyl-glucuronic acid which gives the polyuronides caustic soda solubility. Lignin, the principle noncarbohydrate polymer, is built up from phenyl propane units and is probably chemically bonded in the wood to the polyuronides. Both of these latter are amorphous and occur chiefly in the interfiber zone.

Lange (*2*) and later Jayme and v. Köppen (*3*) examined sections of wood under ultraviolet light and were thus able to plot the location and concentration of lignin inasmuch as it absorbs ultraviolet light. This concentration is plotted as curve (a) in Fig. 4. It will be noted that the middle lamella, the interfiber cementing material, consists of about 70% lignin and that appreciable percentages are also present throughout the cell wall.

The third main analytically separated group contains the extractives, Fig. 3. These are essentially the nonpolymeric components of wood and cover a wide range of functions in the original tree. A most important class consists of the sugars which normally concentrate in the ray cells. Resin is concentrated in the epithelial cells, and tannin is found chiefly in the bark although in river driven wood it can be found in the outer layer of the wood where it has migrated. A group of materials known as lignans which may be present in small amounts in certain individual species can be of special importance. For instance pinosylvin, a resorcinollike material present in the heartwood of pines, will inhibit the pulping of such wood by the conventional acid sulfite process. Its action, under low pH conditions, is to preferentially react with the lignin grouping that would otherwise be sulfonated. The phenol lignin thus produced then undergoes a three-dimensional polymerization similar to that in resorcinol resin. As a result of these reactions the wood can no longer be delignified.

CONVERSION OF WOOD TO PULP

With this background we can now turn to the production of pulp. We wish to maintain the inherent strength and durability of the cellulose fiber but to separate one fiber from the next so that these fibers can be reassembled into a sheet of paper or further purified for chemical conversion to viscose, cellulose, acetate, etc.

Groundwood Pulp

Cellulose, which as we have seen, comprises slightly less than half the weight of the wood, has excellent tensile strength, while the presence of lignin in and surrounding the fibers gives them stiffness. When coniferous wood is ground in the presence of water all constituents, other than the water-soluble extractives, are held in the resultant pulp. Considerable power is required and the grinding action is relatively nonselective, that is to say, the fibers are torn with the formation of a considerable amount of fines at the same time as fibers are being separated one from the other. With dense hardwoods the fibrous structure is essentially lost and such pulps have found little, if any, use. However, softwood groundwood has properties which make it desirable for printing papers. The lignin-containing fibers are relatively stiff and do not bond well with the result that the sheet has high bulk and is opaque making it desirable for lightweight sheets like newsprint when strengthened with 15 to 20% of chemical pulp fiber. Groundwood pulps have relatively low brightness although they can be brought to medium value by bleaching with hydrosulfite or peroxide. Groundwood-containing papers, as normally produced, have poor aging qualities and yellow on exposure to ultraviolet light.

Chemical Pulps

In the production of chemical pulps the cementing material of the middle lamella must be dissolved away so that the fibers will separate one from the other. The lignin, as it occurs in the wood, is surprisingly resistant to most reagents. Only two types of reaction have so far proved commercially suitable for removing the lignin from the wood for the production of pulp, namely, alkaline hydrolysis and sulfonation. With the alkaline process sodium hydroxide or a mixture of sodium hydroxide and sodium sulfide is used. The sulfite process uses bisulfite and sulfurous acid or, more recently, bisulfite alone. Any of the above reagents or neutral sulfite solutions can be used for the preparation of semichemical pulps. None of these reagents are completely specific so that coincidental with the removal of lignin all of the other constituents of the wood are subjected to greater or less attack. Thus, conditions are chosen so that the digestion will be completed while an appreciable quantity of lignin still remains in the pulp. This lignin can be subsequently removed by bleach stages under more specific reaction conditions. The relationship between pulp yield and residual lignin content thus becomes of special importance and Fig. 5 illustrates this for sulfite and kraft

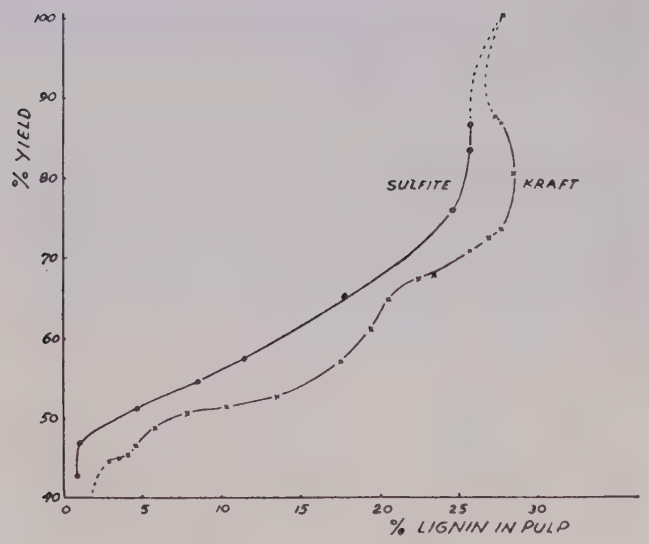

Fig. 5

pulps from spruce (*4*). During the initial stages of the sulfite digestion hemicellulose is rapidly removed and at 80% yield the lignin content is only slightly less than it was in the original wood. As the digestion is carried to progressively lower yields lignin is removed more rapidly than carbohydrate. However, at about 48% yield the lignin content is only 1% and if the digestion is carried further, yield drops off rapidly without change in lignin content. With the kraft process the hemicellulose actually dissolves faster than the lignin during the early stages of the cook and throughout the whole yield range less lignin is removed, at any given yield, than in the case of sulfite. Normally the digestion is stopped in the 45 to 50% yield range for both sulfite and sulfate chemical pulps.

Residual Lignin in the Pulp. The curves (b) and (c) in Fig. 4 show the distribution of lignin throughout the cell wall for sulfite and kraft pulps, respectively, both at 3.6% lignin content. It will be noted that in the case of the sulfite fiber the lignin concentration tends to parallel that of the initial wood. Thus the lignin content of the secondary wall is materially less than that in the primary wall as was the case in the initial wood. With the kraft fiber however, removal of the lignin in the secondary wall slows down in relation to that of the primary wall. This is believed to be due to a swelling action of the alkali on the fiber thus making lignin in the fiber less accessible to the reagent. Attempts to reduce the lignin content of a kraft pulp to a very low value, such as is possible with sulfite, normally result in a serious loss in yield and strength because of this inaccessibility of the lignin in the secondary wall.

The Lignin Pulping Reactions. No complete detailed mechanism for the reactions which result in lignin dissolution has been developed, nor in fact, do we have a satisfactory picture of the chemical structure of lignin itself. However, lignin is made up of substituted phenyl propane units and it seems evident that the initial reaction of bisulfite is with the terminal unit shown for reaction 1, Fig. 6. The R grouping, connected through an ether linkage to the alpha carbon, could be another lignin unit, a simple sugar such as glucose, or more probably a polyuronide. The alpha carbon is activated by the phenolic hydroxyl on the adjacent benzene ring, thus rapidly undergoing sulfitolysis over a wide pH range. It was shown by the author (*5*) that such a product would react with caustic to form a hydroxyl group on the alpha carbon, thus forming an aldol, and sodium sulfite. Such a product will undergo the "reverse aldol reaction" in concentrated alkali to form vanillin and a terminal ketone on the residual lignin molecule. This would account for formation of sodium sulfite and vanillin from the alkaline treatment of lignin sulfonate. The presence of the phenolic hydroxyl in the original lignin is established by the fact that methylated lignin sulfonate yields methylated vanillin. Adler and Lindgren (*6*) have carried out wood sulfonations at various pH values, and compared the reaction rates with various substituted model compounds. By a comparison of reaction rates they have been able to infer the probable lignin structures involved in the sulfonation of lignin.

The lignin grouping shown for reaction 1 is the "X-group" of Adler and Lindgren. They have noted that a second sulfonation can occur at a slow rate at a pH of 9.0 or less and this would result from reaction with the "Y-group" shown under reaction 2. The "Y-group" would be connected through the phenolic ether grouping to another phenyl propane unit. A further sulfonation will occur only at low pH or after hydrolysis and this reaction would be with the so-called "B-group" shown for reaction 3. After hydrolysis of the "OR-group" on the alpha carbon the "Y-group" would result which would then further sulfonate. An ether linkage of the lignin with a polyuronide through the alpha carbon would be consistent with the fact that lignin cannot be extracted from the wood in the absence of conditions which would first involve the cleavage of such bonds. The formation of so-called methyl alcohol lignin and related products would also involve reaction at the alpha carbon.

The reactions in the alkaline process are not as clearly defined as those for the sulfite process. Entkvist and Moilanen (*7*) who have studied these reactions in relation to model compounds believe that the chief caustic reaction is a cleavage of the phenol ether groups shown for the Y and B groups in Fig. 6. This would then activate the alpha carbon and reaction with sodium hydrosulfide would then result in a cleav-

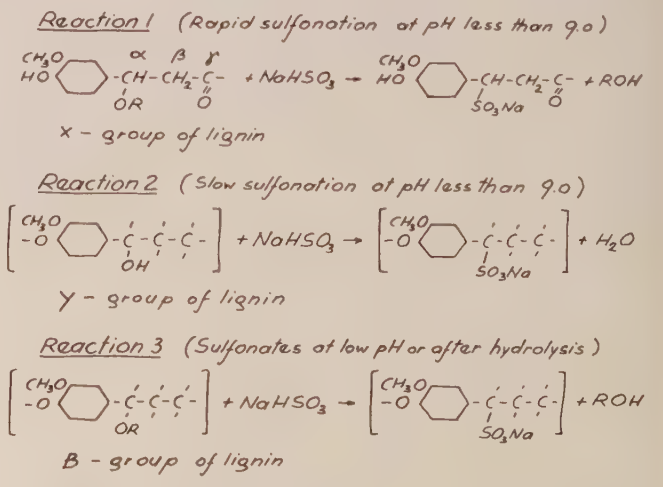
Reaction 1 (Rapid sulfonation at pH less than 9.0)
+ NaHSO3
+ ROH
X - group of lignin
Reaction 2 (Slow sulfonation at pH less than 9.0)
+ NaHSO3
+ H2O
Y - group of lignin
Reaction 3 (Sulfonates at low pH or after hydrolysis)
+ NaHSO3
+ ROH
B - group of lignin

Fig. 6. Reactions involved in sulfite pulping

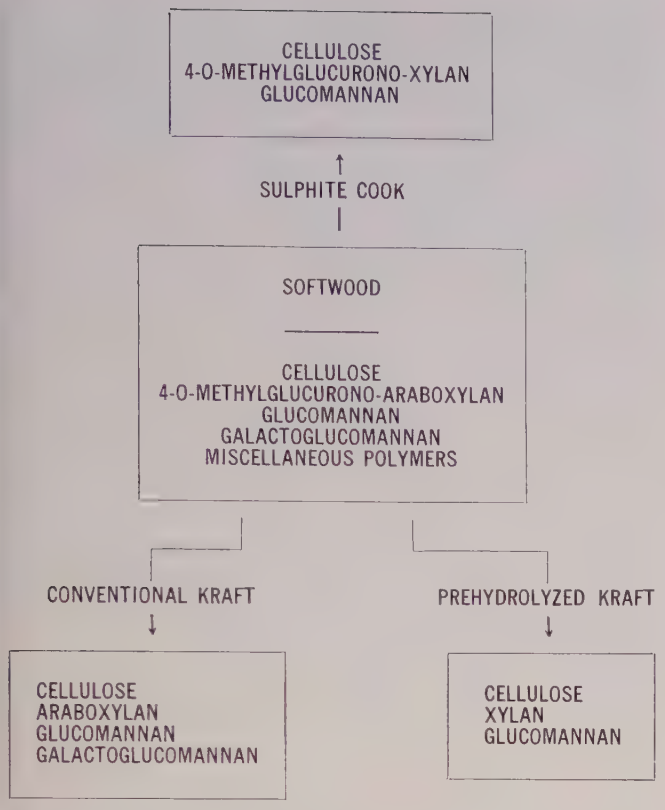

Fig. 7. The behavior of certain carbohydrate polymers of wood during pulping. (Hamilton & Thompson)

age of the OR groups. These investigators believe that the R would be a second lignin unit, but this could no doubt also be a polyuronide. They also believe that the resultant simple phenyl propane units which would go into solution react to form lignin molecules through a carbon-carbon bridge joining the benzene ring ortho to the phenolic hydroxyl with the aliphatic chain of another unit to form the so-called alkali lignin. This would account for the formation of isohemipinic acid from oxidized methylated alkali lignin.

Carbohydrates in Various Pulps. The pulping reactions also modify the nature of the noncellulose carbohydrate remaining in the different pulps. Jorgensen (*8*) has subjected pulps produced from spruce to hydrolysis and determined the nature and the ratio of sugars thus obtained. His results for pulps obtained in the 52 to 55% yield range are shown in Table I. Data are presented for kraft, sulfite, bisulfite, and a two-stage cook where after partial cooking with bisulfite sodium carbonate was added to increase the pH to 7.5 to 9.0. It will be noted that the glucose and mannose content of the kraft pulp is materially lower, while the content of the pentose, arabinose, and xylose is higher than those of the other pulps. The glucose content, which is an index of the true cellulose content, was higher for the bisulfite pulp than for the acid sulfite pulp and still higher for the two stage cook. The last column of Table I shows the change in "cellulosic" glucose content from that of the original wood, after correcting for glucose in glucomannan. It will be noted that the bisulfite pulp shows no loss, acid sulfite a slight loss, while the kraft and two-stage sulfite show rather large losses in glucose.

The End Group Peeling Reaction. In general, it can be concluded from the above that when kraft pulps

Table I. Carbohydrate Content of Various Pulps at 52 to 55% Yield

	Yield, %	*Roe No.*	*Composition of carbohydrates* — *Glucose*	*Mannose*	*Arabinose*	*Xylose*	*Change in cellulose content from wood*
Kraft	52.3	7.0	82.9	6.6	1.1	9.4	−9.3
Acid sulfite	52.1	2.3	85.2	9.8	...	5.0	−1.4
Acid bisulfite	54.9	6.2	87.4	7.8	...	4.8	+1.8
Two-stage bisulfite soda	51.9	11.9	88.0	7.4	...	4.6	−13

are brought to the same yield range as sulfite pulps they contain considerably more lignin and pentosan and materially less cellulose. This loss in cellulose appears to result from the "end group peeling reaction" which occurs in alkali.

Franzon and Samuelson (*9*) have studied the action of alkali on cellulose. They find that, starting with a normal terminal aldehyde group, approximately 65 glucose units will "peel off" until the reaction stops with the formation of a terminal carboxylic group. Machell, Richards, and Sephton (*10*) have shown the series of reactions of Fig. 8. They believe that the "peeling" reaction on the terminal glucose unit of cellulose containing $n + 1$ glucose units shown as (1) in this figure follows through (II), (V), (VI), (VII) to yield (VIII), D-glucoisosaccharinic acid and a new terminal glucose unit in a cellulose molecule containing n glucose units which can undergo further degradation. The competing reaction of (I) through (II) and (III) results in (IV) which is a cellulose having $n + 1$ units but with the D-glucometasaccharinic acid terminal group. This is stable and will not "peel off" further. The greater tendency to follow the "peeling off reaction" via route (I) to (VIII) results, in the average, on a loss of about 65 glucose units before it is stopped by it following the "stopping reaction" via route (I) to (IV).

The Pentosan Fraction. When pulps are purified for chemical conversion to viscose, acetates, etc. such treatment includes an alkaline digestion stage as part of

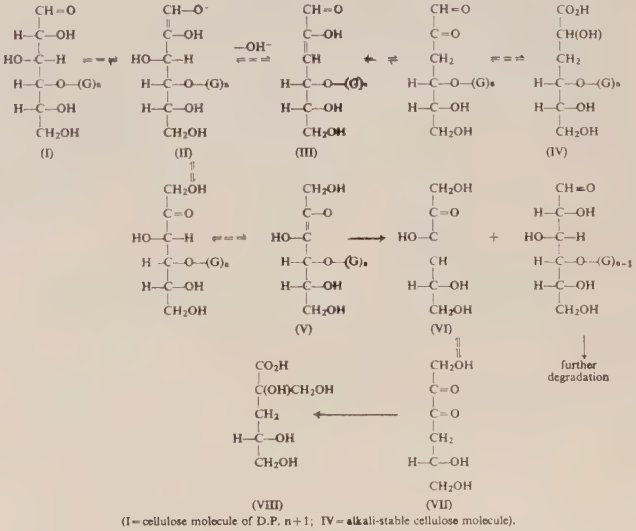

Fig. 8. The cellulose peeling reaction I → II → V → VI → VII → VIII. The cellulose stopping reaction I → II → III → IV. (From Machell, et al.)

the bleach sequence which reduces the noncellulosic carbohydrate content. Because of the resistance of the pentosans to alkali it is not possible to reduce pentosan content at this stage. Thus when the kraft process is used for the production of dissolving pulps the chips are first subjected to an acid hydrolysis to reduce pentosan content before the actual digestion. Hamilton and Thompson (*11*) have characterized the actual noncellulosic polymers in pulps and a chart from their recent paper is shown in Fig. 7. It will be noted that the polyuronide 4-O-methylglucurono-araboxylan of the wood is converted to 4-O-methylglucurono-xylan in sulfite pulp, araboxylan in kraft pulp and xylan in the prehydrolyzed kraft.

Ylnen, Östberg, and Stockman (12) have established that during the alkaline cook about half of the xylan present in the final pulp first goes into solution, presumably during the breakdown of the 4-O-methylglucurono-araboxylan, and is then redeposited on the fiber.

The Effect of Sodium Borohydride in Alkaline Pulping. Hartler (13) has investigated the effect of adding sodium borohydride to the normal kraft liquor. The results obtained in cooking pine, with and without borohydride are as follows:

	No borohydride used	*2.1% borohydride used*
Total pulp yield	46.7	52.1
TAPPI viscosity, cp.	77	62
Lignin in pulp, %	3.9	3.7
Glucose in pulp, %	85.1	81.4
Mannose in pulp, %	5.6	13.8
Xylose in pulp, %	8.1	4.1
Glucomannan as per cent of that in original wood	28	79
Xylan, as per cent of that in original wood	78	52

Borohydride will reduce the carboxyl group to the hydroxyl group and therefore should stop the alkali peeling reaction, at least before the borohydride is destroyed through side reactions. The effect obtained was a markedly increased yield, through retention of glucomannan. However there was a loss in xylan when compared with the normal pulp. Hartler established that the xylan, which dissolved from the wood, was capable of redepositing from the liquor on cotton but not on the pulp. He thus assumed that the glucomannan in some way blocked its readsorption on the kraft fiber. Because of the present cost of borohydrides such an addition is not commercially attractive. However, this experiment is of great theoretical interest and could point the way to some practical means of increasing alkaline pulp yield.

Effect of Cellusans and Polyuronides on Pulp Properties. The presence of the cellusans and polyuronides in cellulose is normally considered desirable for paper pulps. The presence of these materials in the fiber, with their characteristic swelling properties, tend to show a cooperative effect with the mechanical beating action thus opening up the fiber and causing fibrillation.

Depolymerization of Cellulose in Pulping. In addition to actual loss of hemicellulose and cellulose the residual cellulose in the pulp becomes progressively depolymerized during the course of the digestion and subsequent bleaching stages. The degree of polymerization is normally indirectly measured by the viscosity of the cellulose after dissolving in cupriethylenediamine solution at a concentration of 0.5%. Normally the digestion should be stopped, in the case of a kraft pulp, while the degree of polymerization is above about 1500 glucose units corresponding to a viscosity of about 30 or better. With modern bleaching techniques this allows the production of a bleached pulp with a degree of polymerization of better than 1300. The strength of the pulp drops off systematically and gradually with decrease in viscosity in this range. As the degree of polymerization is decreased below 800 strength drops off rapidly and at about 200 the pulp becomes useless.

With sulfite pulps the strength is lower, for any given viscosity, than that of kraft pulps even when both pulps are prepared from the same wood. It has been suggested (*4*) that this results from a greater tendency for the sulfite cellulose molecules to cleave at faults that might form in the fiber than in the case of kraft pulps. This could explain why viscose fibers are considerably stronger than the sulfite pulp from which they were prepared, presumably because the cellulose molecule would be randomly spaced in the reformed fibers. It should be noted that mechanical damage to the chip prior to pulping has a greater effect on pulp strength with the sulfite process than with the kraft process. The development of new chipping methods can result in markedly better strength for sulfite pulps.

Semichemical Pulps

Semichemical pulps are becoming of increasing importance. In these pulps the digestion is stopped at a point prior to that in which the middle lamella has completely dissolved and mechanical action is therefore required to defiber the softened but not fully pulped chips.

Hardwoods. The first pulp of this type produced in any significant quantity was the neutral sulfite semichemical pulp produced from hardwoods. If the digestion is stopped at about 75% yield a pulp producing rather dense papers, suitable for corrugating medium is obtained. If the digestion is continued to give a yield of about 65% the pulp can be bleached for use in fine papers. Bleach requirements are high and the cost of this pulp is normally higher than that of bleached hardwood pulp produced by the kraft process or the bisulfite process.

There is presently considerable interest in very high yield hardwood pulps obtained at about 90% yield. These can be obtained by the so-called cold caustic treatment, or by digestion with neutral sulfite or bisulfite. The softening effect of the chemical allows mechanical separation of the individual fibers, which is not possible with untreated hardwood. These pulps can be partially bleached with peroxide and hydrosulfite without any essential loss in yield to give opaque and bulky pulps.

Softwoods. Very high yield pulps (85 to 90%) can also be produced by the neutral sulfite and bisulfite process (but not suitably with cold caustic) from softwoods. These can also be semibleached and their bulk and opacity approaches that of regular groundwood, but their strength is materially better.

Semichemical softwood pulps are presently being produced at about 65% yield by the acid sulfite process for newsprint. The use of bisulfite pulps for this purpose is also being considered but probably at a somewhat higher yield.

Modifications of Pulping Processes

The use of caustic soda only, without sulfide, is now essentially obsolete in alkaline cooking. The presence of sulfide, which accelerates the delignification reaction, allows the use of shorter cooking times with resultant decreased pulp degradation. It is apparent that further improvement, such as that possible with sodium borohydride, is possible. Now that this has been theoretically established it seems probable that other methods will be found.

The sulfite process now appears to be undergoing major change. The use of bisulfite alone instead of bisulfite and excess sulfur dioxide allows the pulping of pine. It can also result in pulps having better yield and better strength than can be obtained by the conventional process. Other modifications, starting with bisulfite, involving two-stage treatments are also of interest. By increasing the pH part way through the cook better strength is realized. Decreasing the pH, by the addition of sulfur dioxide, results in pulp with easy beating properties.

Various other pulping processes have been proposed but none of these have met with economic success. These include the so-called hydrotropic process which uses sodium xylene sulfonate as the digestion reagent, the nitric acid process, and others.

BLEACHING

Chemical pulping of wood should be considered as one stage of a multistage delignification process. The final delignification is carried out by bleaching. In general sulfite pulps bleach more readily than kraft pulps. The sulfite cook appears to "open up" the cell wall of the fiber as previously mentioned in connection with the discussion of curves b and c of Fig. 4 and normally it contains considerably less lignin than the corresponding kraft fiber.

Bleaching Agents

It is not possible to effectively bleach chemical pulps with any single bleaching stage and kraft pulp requires one or two more stages than sulfite pulps for any given brightness. Normally the first stage of a bleaching sequence involves an aqueous treatment with elemental chlorine. This results in a chlorination of the lignin, a portion of which becomes water soluble, and dissolves out. A caustic stage, as a second stage, results in a further solution of chlorinated lignin but still leaves the pulp at a relatively low brightness level. The caustic stage also removes some of the resin and the hemicellulose. In producing high purity pulps for viscose, etc. high concentrations of alkali accompanied by high temperatures are normally employed to decrease the hemicellulose content, which results in a considerable loss of yield. With kraft pulp a second chlorination followed by an additional alkaline treatment may next be used. A portion of the lignin is apparently not accessible to the chlorine in the first treatment but becomes so after the initial chlorine and caustic stages. This secondary chlorination was considered essential for the production of high brightness kraft pulps before the use of chlorine dioxide stages was introduced but now can be eliminated. Following the caustic stage a "true bleach" or oxidizing stage is normally employed. Originally hypochlorite was used but this has a strongly degrading effect on the cellulose if sufficient reagent is added to remove any substantial amount of lignin. Chlorine dioxide is a specific oxidizing agent for phenols. With sulfite pulp a brightness of 86 to 88 G.E. can be obtained by a sequence consisting of chlorination, caustic extraction, and chlorine dioxide. The brightness can be further increased to better than 90 G.E. and the brightness stability materially improved by following this with a high pH hypochlorite or peroxide stage. With softwood kraft pulps a sequence consisting of chlorination, caustic extraction, chlorine dioxide, caustic extraction, chlorine dioxide is now frequently used. In addition to these stages a hypochlorite or peroxide stage is sometimes added. The large number of stages used is related to the topochemical nature of the reactions involved.

Brightness Stability

One of the most important properties required in a bleached pulp is that the brightness should be stable so that the pulp will not yellow on standing. The traditional methods for improving stability are the use of high pH hypochlorite or peroxide. Recently, Rapson (*15*) has compared the effect of chlorine dioxide at pH 6.8, peroxide at pH 10, sodium chlorite at pH 4.0, and sodium borohydride at pH 10. The effectiveness of these reagents for stabilizing brightness which, in the case of chlorine dioxide is essentially nil, increases in the order named. Acidified chlorite will convert carbonyl groups to carboxyl while borohydride will convert carbonyl to hydroxyl. These reagents also decrease the hot alkali solubility of the pulp. As noted in the discussion of the Rapson paper, brightness instability can develop if cotton pulp is treated with hypochlorite at pH 7.0 which also increases the carbonyl content. This pulp can then be stabilized with chlorite. Thus brightness instability is definitely associated with the carbonyl group of the cellulose and is not related to residual lignin as is reported in some texts. However introduction of aldehyde carbonyl groups by means of periodate does not increase brightness instability and studies which would definitely establish the actual location of this carbonyl, possibly a ketone on the no. 2 carbon, would be of considerable theoretical interest.

CHEMICAL RECOVERY

The Kraft Process

A most important aspect of pulp production is the fate of the residual liquor. At the time that the alkaline process was first used alkali was being commercially produced by burning wood and recovering and causticizing the potash from the ash. Thus it was natural that the residual liquor should have been collected, evaporated and burned to establish a cycle for the alkaline recovery. Whereas chemical recovery thus goes back 100 years or more, methods remained extremely primitive and little use was made of the liberated heat. About 30 years ago efficient methods

were developed for burning the liquor. A portion of the alkali volatilizes and forms a fume. If this condenses on and around the boiler tubes under temperature conditions where it can melt or slag it will quickly block off the gas space and the furnace will become inoperative. The solution of the problem involved the use of a water-wall furnace, i.e., where the wall of the furnace is built from tubes which are used for preheating the feed water. The boiler tubes are placed high enough above the flame zone so that the gas is sufficiently cooled to maintain deposited fume in the form of a light dust. Provision for periodic soot blowing and lancing thus keeps the tubes clean, the material dropping to the hearth where it melts and is carried from the furnace

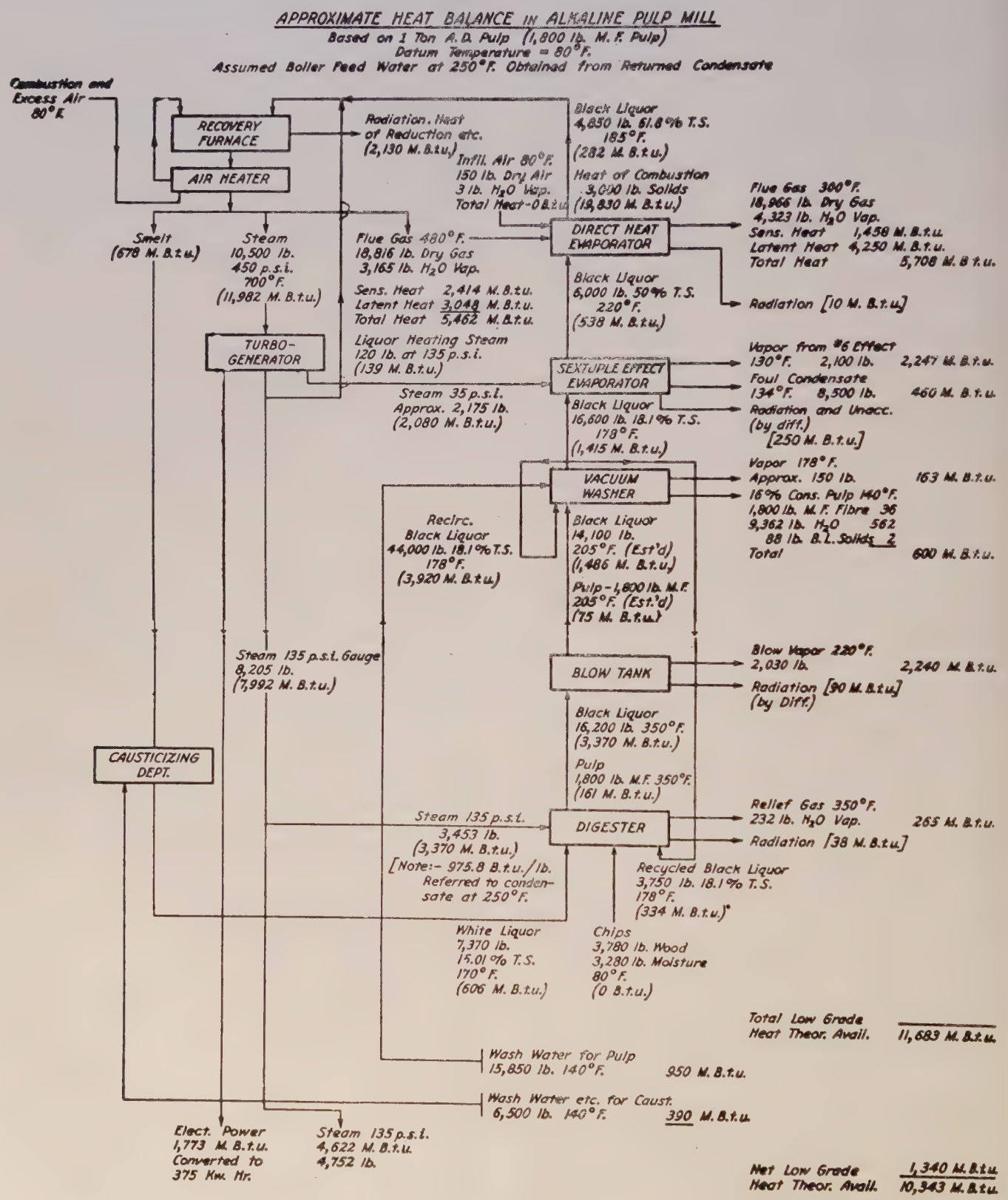

Fig. 9. Heat balance

through the smelt spout. With this equipment it is possible to recover more than ample heat for cooking, evaporation, etc.

An overall heat and material balance for the alkaline pulp mill is shown in Fig. 9 (*14*). The total heat of combustion of the black liquor solids from one ton of pulp is 19,830M B.t.u. The primary steam produced amounts to 10,500 lb. per ton of pulp at 450 p.s.i. and 700°F. or 11,982M B.t.u. Of this, 1773M B.t.u. are converted to 375 kw.-hr. electric power and after subtracting theoretical steam requirements for evaporator and bleaching leaves a net quantity of 4725 lb. steam at 135 p.s.i. Heat from the digester is distributed between the relief and blow, the black liquor, and the washed pulp. The liquor then passes to the sextuple effect evaporator, the direct heat evaporation, and finally to the furnace closing the cycle. In the right side of Fig. 9 is shown the quantity of low grade heat available in vapors, flue-gas, etc. This totals 11,683M B.t.u., approximately the amount of heat generated as primary steam. Much of this can be recovered in the form of hot water of which about 1340M B.t.u. are returned to the cycle for washing pulp and the calcium carbonate sludge from the causticizing operation. The balance is available for use in bleaching, at the paper machines, or elsewhere. At the Howard Smith mill in Cornwall we are now recovering secondary heat in the form of hot water at 145°F., equivalent to 9600 lb. steam per ton of pulp from the flue gas, evaporator vapors, and blow. This is used in the bleach plant and for other process purposes materially improving the heat economy of the operation.

The smelt from the recovery furnace contains the sodium salts in the form of sodium sulfide and sodium carbonate. A solution of these, treated with hydrated lime, results in conversion of the carbonate to caustic thus regenerating the original cooking liquor. Sodium sulfate is added to the residual concentrated liquor, prior to combustion to make up for incidental losses of sodium salts. Reducing conditions are maintained on the furnace hearth to convert sulfate to sulfide, but an oxidizing condition must be maintained in the upper zone to prevent the production of hydrogen sulfide with consequent undesirable odor. Hydrogen sulfide and mercaptans are also released at the digestion and in the evaporators. It has been established (*16*) that if the residual liquor is oxidized with air the mercaptan and sulfide are converted to more stable form and the liquor can be evaporated without sulfur loss and that it may also be contacted with the hot furnace gas where it is further evaporated, simultaneously picking up sulfur-containing gases from the flue gas. Such processing materially reduces odor, particularly when combined with proper condensing and oxidation of the digestion gas. As a result of this reduction in sulfur loss, independent of sodium loss, it is necessary to reduce the input of makeup sodium sulfate, substituting a portion with sodium hydroxide.

Sulfite Process Recovery

Whereas all the alkaline chemical pulp mills have operated from the beginning with recovery systems not a single sulfite mill operated in this way until quite recently. The cost of chemicals for a calcium-base mill is of the order of $5.00 per ton of pulp while that of an alkaline mill would be $25 per ton of pulp for straight sodium hydroxide digestion liquor and even somewhat more for the sulfide content liquor normally used. Whereas the sulfite mills have been able to economically operate without recovery, the study of this recovery problem has been one of the major concerns of the industry inasmuch as the discharge of the residual liquors has caused serious pollution problems in many areas.

Magnesia-Base Recovery. It was established (*17*) that when using a magnesium-base liquor, recovery is possible. When the residual liquor is separated, evaporated, and burned the products of combustion contain the sulfur in the form of sulfur dioxide and the magnesia in the form of a readily separated magnesia ash. By slaking this latter, suspending it in water, and contacting with furnace gas, magnesium bisulfite is formed which can be recycled in the system. As it turned out, this has proved to be the simplest recovery system yet developed. The heat recovery is also higher than that for the kraft process inasmuch as the ash carries through the boiler section. Over 20% of United States sulfite production is now made with this system.

Soda-Base Recovery. When a soda-base sulfite liquor is separated, evaporated, and burned a smelt containing higher sulfide than that obtained in the smelt from the kraft process is obtained. If this liquor is treated with carbon dioxide most of the hydrogen sulfide is liberated which may then be burned to sulfur dioxide in the recovery unit and used for sulfiting the carbonated liquor. This process, known as the Mead process, is used for neutral sulfite semichemical pulp liquor recovery. A simpler process, the Institute process, involves a direct sulfiting of the smelt and this has also been used for the neutral sulfite process. A considerable amount of sodium thiosulfate is formed in the recovered liquor and also to a lesser extent in the recovered liquor produced by the Mead process. Since this is undesirable for acid sulfite and bisulfite pulping more complex processes have been developed to reduce the thiosulfate content.

The Stora Kopparberg process uses a high concentration of carbon dioxide which is separately cycled and is used to liberate hydrogen sulfide from the sodium sulfide. Sulfur dioxide is produced from the hydrogen sulfide in a secondary system and is then used for sulfiting the stripped carbonate solution. In the Western Precipitation process the sodium sulfide and carbonate are separated from one another and the sodium sulfide mixed with the residual liquor, oxidized, evaporated, and returned to the furnace. Sulfur dioxide released from the furnace is absorbed in the sodium carbonate. In the Sivola process the carbonate is converted to bicarbonate which is filtered off. Hydrogen sulfide liberated from the sulfide is burned to sulfur dioxide and this, plus sulfur dioxide from the furnace, are used for sulfiting the bicarbonate. In the Rayonier process the sulfide and carbonate are first separated and the hydrogen sulfide which is separated from the sodium sulfide is converted to sulfur dioxide in secondary equipment and then combined with the sodium carbonate. This process would result in a minimum of thiosulfate in solution since the carbonate is separated

from the sulfide and a purified sulfur dioxide, rather than flue gas (which may contain hydrogen sulfide) is used.

In addition to these processes there are also ones that have been considered using novel methods of burning the liquor. In the Zimmerman process the liquor is burned by "wet combustion" under high temperature and pressure. By the Gauvin atomized suspension technique the liquor is first pyrolized to a solid in a special vessel and the solid collected and separately burned. Ion exchange methods have also been proposed. Most of these methods have been reviewed by O'Donoghue (*18*).

BY-PRODUCT RECOVERY

It is possible to recover certain valuable by-products from the liquor which have a greater value, when isolated, than as fuel. For instance tall oil and lignin, dimethyl sulfide and methyl mercaptan are being recovered from kraft liquors. Vanillin, alcohol, yeast, and lignin sulfonates are recovered from sulfite liquors. Production of such material is often quite attractive but in most cases only limited markets, in relation to the potential supply, appear available.

In general, pulp should be produced in maximum yield in relation to the desired final product, efficient methods of heat and chemical recovery should be used, and where possible, by-products should be made and marketed.

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The Science of Chemical Additives in Papermaking

JOHN W. SWANSON

Few papers are made from cellulose fibers alone —most contain other materials which are added during preparation of the fibers or later to the paper web either in the drying section of the machine or during a separate off-machine operation. In many instances huge quantities of such materials are used. Table I presents a partial list of these materials, their principal uses, and annual consumption in tons. It is apparent that the industry is a good customer for many chemical products of both natural and synthetic origin. As a matter of fact, the paper industry is the largest consumer of white clays, is second only to the food industry in the consumption of starches, and is the third largest user of all industrial chemicals. Many more unlisted products are used in the industry for special purposes. In summary, it might be said that the magnitude of annual paper and board production—some 38 million tons—attracts many new products from the chemical industry each year. The addition of even 0.1% of an additive based on such volume production represents an attractive market. In some large tonnage products, such as coated papers and impregnated papers and boards, the additive may become a major component of the final paper structure.

The purpose of chemical additives is to improve a property of the paper or paperboard which is otherwise deficient. For example, starches and gums are used to supplement the beating and refining operation and to improve fiber-to-fiber bonding and dry strength properties. Urea-formaldehyde, melamine-formaldehyde, and other synthetic polymers are employed for improving wet strength of papers and boards. The sizing agents make papers resistant to penetration of certain liquids. Clays and other pigments improve brightness, opacity, and printing properties. Surface-active agents are incorporated with paper towels and other absorbent products to insure absorbency. In other instances, surfactants are used as felt washing compounds, detergents for recovery of wastepaper, combatting foam troubles, or pitch troubles, etc. For all such purposes, the matter of economics is an important consideration and, in general, a minimum of material is used to accomplish the desired benefit.

Sometimes the papermaker finds that the chemical additive is less effective than he would like. On other occasions he may find that the benefit obtained in one property is offset by a detrimental effect upon another property. This latter instance is frequently encountered where additives are placed in the furnish at the beaters or wet end of the machine before the sheet is formed. For example, a manufacturer of an opaque paper may add a polymer adhesive to the stock to improve fiber bonding, but he finds that retention of the opacifying pigment then becomes so poor that the

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optical properties are deficient. In another example, a manufacturer of an absorbent paper adds a surface-active agent to the furnish in order to assist rewetting or to combat the gradual development of self-sizing or water resistance. He may find that sufficient surface-active agent to prevent self-sizing reduces tensile strength to an intolerable level or produces excessive foaming in the stock. Papermakers who encounter such problems may quarrel with the word "science" in the title of this paper, preferring to believe that the subject concerns a great deal of "black art." To these let me offer the hope of demonstrating that science does bring order and a certain amount of understanding to a complex subject. To those scientists, engineers, and professors who are less well acquainted with the paper industry, I hope it may become apparent that the science of chemical additives in paper presents many very interesting applications of fundamental law and even more interesting problems for further research.

It would be impossible to discuss individually all kinds of additives that are used in paper. Indeed, if this were done as completely as possible today, tomorrow it would be necessary to add several new materials. In the following sections of this paper, additives will be discussed in terms of their various classified uses. Those additives which affect paper strength, fiber distribution in the sheet, surface properties, optical properties, foam, pitch, etc., will be considered. Even this classification will be abridged because of time and space limitations.

ADDITIVES WHICH AFFECT STRENGTH PROPERTIES OF PAPER

When the strength of a sheet of paper is considered in fundamental terms, the question often arises—what basic factors control the final strength? Considerable research has been done on this problem and while some of these basic factors are at present probably unrecognized, we know that the following properties are important in many types of papers and boards.

1. Chemical and physical composition of the fiber
2. Fiber dimensions
3. Fiber strength
4. Filtration resistance
   (a) Hydrodynamic surface area
   (b) Swollen volume
5. Fiber flocculation
6. Bonded surface area
7. Unbonded surface area
8. Bonding strength per unit bonded area
9. Distribution of bonds (sheet formation)
10. Stress distribution
11. Fiber conformability (flexibility)

In considering a list of such basic factors, it may be assumed that additives which are placed in the fiber-water system will have little effect, in general, upon fiber length, fiber strength, and possibly fiber conformability. However, many additives are known which affect bonded area, bonding strength per unit bonded area, fiber flocculation, the distribution of bonds or sheet formation, and, possibly, stress distribution. Therefore, when the effects of any additive are considered, it is necessary to have an understanding of the mechanism of interfiber bonding and, to some extent, fiber flocculation. To provide a common basis of understanding of the effects of additives, let us briefly review the nature of adhesion and the mechanism of strength development in a sheet of paper as it dries. The role played by some of these factors will become clearer as the discussion proceeds.

The Nature of Adhesion and Fiber-to-Fiber Bonding

It is generally recognized in the field of adhesion that secondary molecular forces play a dominant role in bonding similar and dissimilar materials together. The following facts strongly indicate that the strength of paper depends upon such molecular forces and not upon mechanical entanglement and frictional effects between fibers and fibrils. This has been discussed previously by Swanson (*1*, *2*) and these remarks are taken largely from these articles.

1. When water in a wet sheet is displaced by an organic solvent and the sheet is dried, very little or no strength exists.
2. When the water in a wet sheet is frozen rapidly and sublimed below the freezing point, the sheet is very weak.
3. Paper sheets formed from pulps suspended in dilute solutions of surface-active agents are very weak.
4. Certain pulps which fibrillate extensively upon beating will not yield strong paper even when both the beating and sheet preparation are done in water.
5. Load elongation studies show that papers exhibit both "primary creep" and "secondary creep." Strain-hardened papers from which secondary creep has been removed may be repeatedly strained and relaxed without damage to their structure. This behavior would hardly be expected if the strength of paper depended primarily upon frictional effects.

Fundamentally, bonding of cellulose fibers as well as their sorption of water and of many other low and high molecular weight materials in the papermaking system occurs because of the fact that all atoms and molecules attract each other with characteristic valence forces. In addition to the primary valence forces which form the molecule or chemical compound, residual attractive forces exist between such molecules. These so-called secondary forces, or Van der Waals' forces, are those which lead to the aggregation of molecules into liquids and solids and to the formation of crystalline forms of matter. Although formation or rupture of secondary valence bonds involves lower energy changes (0.5 to 10 kg.-cal. per mole) than primary valence bonds (20 to 200 kg.-cal. mole), residual forces are extremely important in adhesion phenomena. These residual forces are of three main types:

1. The Keesom or orientation forces which exist between rigid dipolar molecules.
2. The Debye or induction forces which result from the action of dipolar molecules on a polarizable nonpolar molecule.
3. The London or dispersion forces which exist between all types of molecules—polar as well as neutral.

The equations expressing the attractive energies for these three effects are presented below:

$$U_0 = -\frac{2\mu^4}{3kTr^6} \qquad (1)$$

$$U_I = -\frac{2\alpha\mu^2}{r^6} \qquad (2)$$

$$U_D = -\frac{3h\nu_0\alpha^2}{4r^6} \qquad (3)$$

where

μ = dipole moment of the molecule
k = Boltzman's constant
T = absolute temperature
r = distance between the molecules
α = polarizability of the molecule
h = Planck's constant
ν_0 = characteristic frequency of the molecule

The forces of attraction corresponding to the above energies may be obtained by differentiation of the equations with respect to the distance.

The induction effect (U_I) is small for most molecules. The London effect (U_D) always produced considerable molecular interaction; but the orientation effect (U_o) is of major importance with substances possessing a relatively high dipolar character.

When the geometry of the molecules is favorable in a given system, and a hydrogen atom is attached to a strongly electronegative atom such as nitrogen, oxygen, the halogens, or sulfur, the hydrogen atom may be shared between two sets of electronegative groups. This forms the so-called hydrogen bond. Such H-bonds have energy values from 3 to 8 kg.-cal. per mole depending upon the particular atoms and the distances involved.

Much work remains to be done in the field of molecular forces, especially in such complicated systems as those represented by cellulose fibers. However, the important considerations here are that these intermolecular forces of attraction are exerted in all directions. This means that molecules existing in the surface layers of solids and liquids, and upon the corners and edges of solids, are not satisfied in one or more directions. The tendency for such surface molecules of solids to satisfy their residual attractive forces produces the phenomena of adsorption and absorption as well as flocculation of materials possessing high specific surface areas. These forces are responsible for adhesion of solid high polymers when sufficient intimate contact on a molecular scale can occur. The important facts to bear in mind for fiber bonding are the following:

1. Hydroxyl groups viewed on a molecular scale are strongly polar.
2. Papermaking pulp fibers have a multitude of hydroxyl groups which are potentially capable of interaction by the orientation effect, and by hydrogen bonding, as well as by the London, or dispersion, effect.
3. The attractive forces mentioned above decrease with the inverse seventh power of the distance. Therefore, elements of the fiber surface which are to be bonded together must approach one another very closely if these forces are to become effective. The distance of separation should be no more than a few Angstrom units.
4. Rigid solid surfaces are very rough and the real area of contact on a molecular scale when two such rough surfaces are brought together is very small.

It becomes clear, therefore, that one of the most important aspects of papermaking is to prepare the fibrous material in such a form that intimate contact can be attained between fibers and fibrils on a molecular scale. This is one of the primary reasons for beating and refining pulps. It is also one of the basic reasons for the use of beater or wet-end adhesives in such systems. These materials are able to bridge distances between fibers and to establish bonds that would not have otherwise formed between these surfaces.

The evidence that swelling of the fiber and intimate contact of fiber surfaces on a molecular scale are necessary for good fiber-to-fiber bonding has been reviewed by Swanson (*1*, *2*).

Now, if the secondary valence forces and hydrogen bonds are indeed responsible for the strength of the fiber-to-fiber bond and if swelling and greater surface area provide increased opportunity for molecular contact, how are these opportunities utilized? It is well known that a wet sheet made from even highly swollen fibers is still weak after very extensive pressing. Thus, there are very few fiber-to-fiber bonds formed during the pressing operation *or* the fibers must spring back, thereby breaking any bonds which were formed during pressing. There must be, then, some mechanism which brings the fibers into intimate molecular contact during the drying operation. A general theory for this effect was formulated by Campbell (*3*) many years ago and recently experimental data have confirmed the hypothesis. This is now known as the Campbell effect.

The studies of Lyne and Gallay (*4*) on wet-web strength summarize quite clearly the several stages of strength development and the Campbell effect as a sheet of paper is dried. In the first stage, where the paper web is about half-way down the fourdrinier wire and the fiber content is about 8%, the web is held together by surface-tension forces arising from the menisci formed as the water layer recedes into the fibrous structure. This is shown schematically in Fig. 1a.

As long as the radius of curvature of the meniscus is sufficiently large the principal force, F, pulling the fibers together is approximately

$$F = \gamma L \qquad (4)$$

where γ is the surface tension in dynes per centimeter and L is the length of line contact between air, water, and fiber.

As the water recedes into the fiber structure, a second situation develops in which two menisci exist between adjoining fibers (see Fig. 1b) and the compacting force will be approximated by

$$F = 2\gamma L \qquad (5)$$

If one assumes, as Campbell did, that parallel fibers have an average diameter of 3×10^{-3} cm. and the spaces between them in the wet mat are of a similar magnitude, then there would be 166 cm. of length of

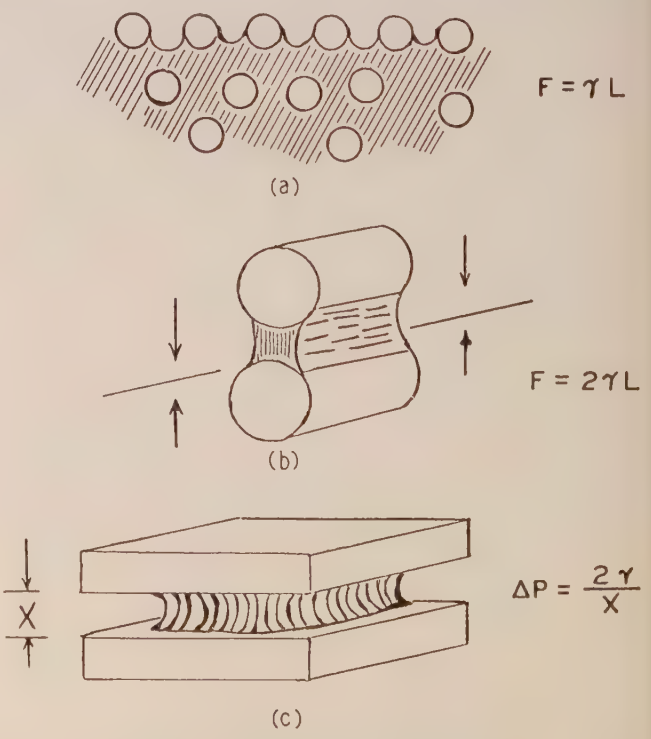

Fig. 1. Schematic diagrams for action of surface tension forces during drying of paper

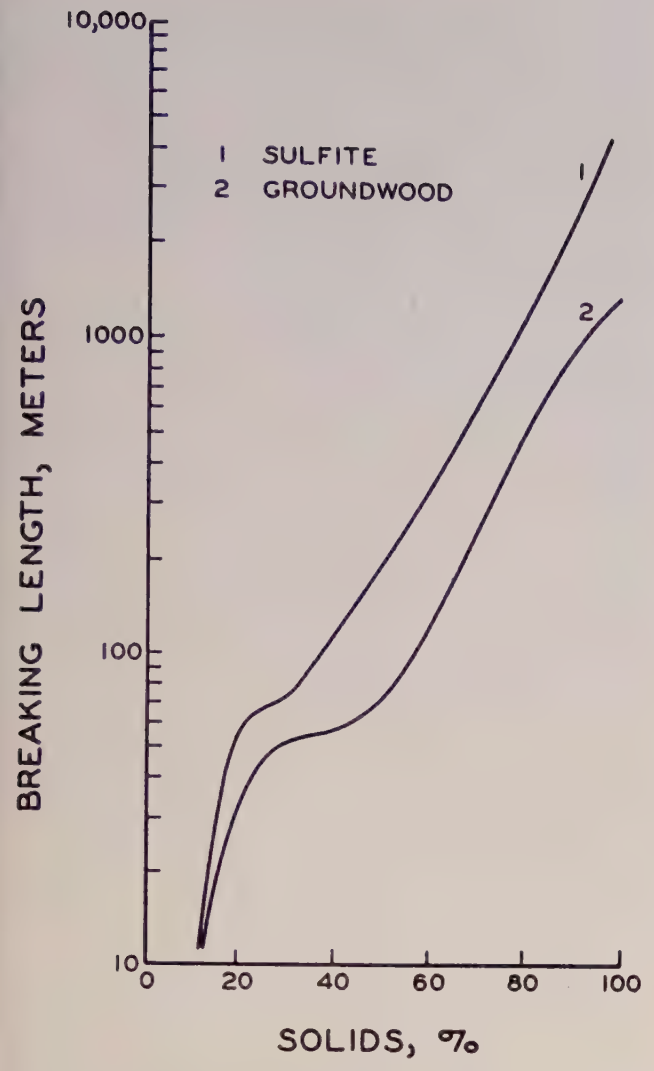

Fig. 2. Development of strength in sulfite, and groundwood webs with increasing dryness, showing detail in the wet web region [From Lyne and Gallay (4)]

contact in the first stage or 332 cm. per sq. cm. of wet web in the second situation when the water level recedes into the structure. Using a figure of 75 dynes per cm. for the surface tension of water, one may calculate for the second situation a compacting pressure of approximately 50 g. per sq. cm. If, by beating the fibers, the average fibril diameter is reduced to one-tenth that of the fiber, and the intervening space is correspondingly reduced, the compacting force increases by a factor of ten to approximately 500 g. per sq. cm. which is about 6 lb. per sq. in. Although this pressure is appreciable, it may not be great enough to produce much fiber-to-fiber bonding. However, this effect is responsible for the development of appreciable wet-web strength as shown in Fig. 2 taken from Lyne and Gallay (*4*).

At about 20 to 25% solids a transitional stage is encountered wherein, because of compacting pressure, sheet density increases, and interfiber bonding begins to occur. In this region the total surface tension forces decrease very rapidly and the water content of the sheet becomes so low that the liquid-water film is discontinuous. This is shown in Fig. 1c. However, the magnitude of the pressure difference caused by the surface-tension forces changes from a dependence upon the total length of fiber-water-air contact to a dependence upon the thickness of the water film held between two fibers nearly in contact. This latter effect may be expressed approximately by

$$\Delta P = 2\gamma/X \qquad (6)$$

where X is the thickness of the liquid film, γ is the surface tension, and ΔP is the compacting pressure. Because this latter pressure is inversely proportional to the film thickness, it reaches high values of the order of 100–200 atmospheres as the sheet approaches dryness.

According to Campbell this is the major effect which is responsible for the final compacting pressure that forces the plastic fibers sufficiently close together for molecular bonds to form during drying. Of course, at any particular moisture content and degree of beating the rigidity of the fibers and the Campbell effect will balance one another. As fibrillation increases with the degree of beating, the average fibril diameter becomes smaller. The rigidity of a beam supported at the ends varies as the fourth power of the cross-sectional diameter. Thus, as beating proceeds the effectiveness of the Campbell pressure becomes much greater because the fibrils become much more flexible and deformable. This produces better fiber bonds and greater fiber-to-fiber bonded area.

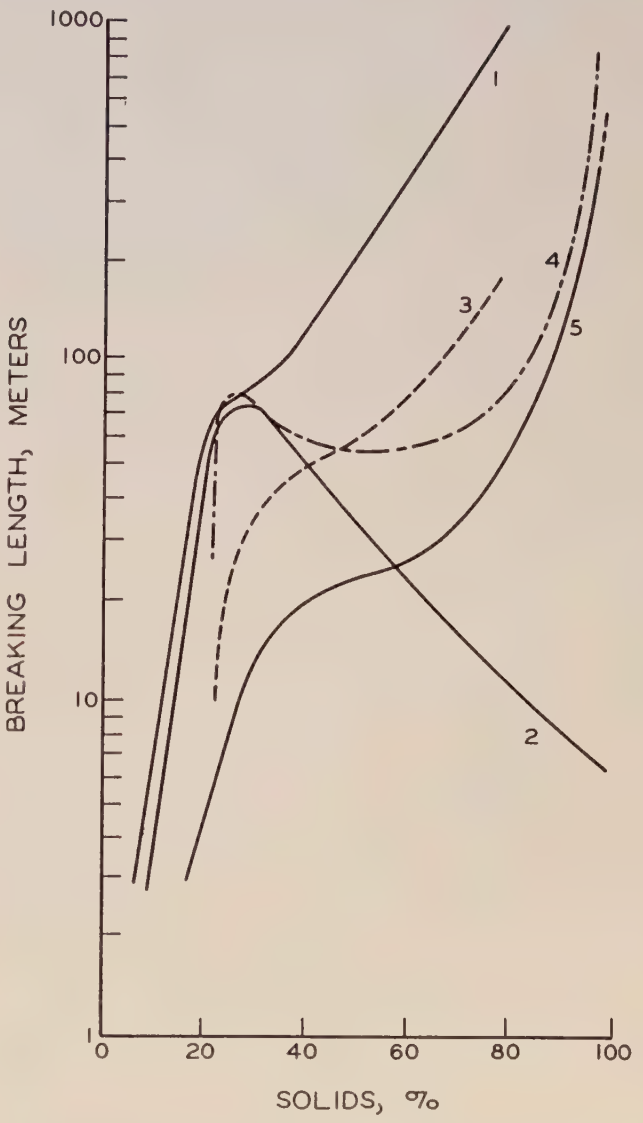

Fig. 3. Effect of bonding agents on strength development of glass fiber webs [From Lyne and Gallay (4)]

The validity of the Campbell effect has been confirmed by Van den Akker (*5*) and more recently by others (*6*, *7*). Van den Akker showed that if the water in a wet web is rapidly frozen and then sublimed below the freezing point the resulting sheets are very weak. Under these conditions the surface forces do not exist or are not effective and the Campbell effect is inoperative. Similarly, we should expect that if surfactants are used in the furnish, lower strength should result because the surface tension of the water will be lower. This is found to be the case.

The several stages of strength development may be more clearly separated by using fibers which are incapable of forming hydrogen bonds but which are of comparable diameter. [See Fig. 3 taken from Lyne and Gallay (*4*).]

It is noted for 2.5 μ glass fibers in water (curve 2) that only the surface-tension forces hold the sheet together until the water content gradually becomes so low that strength decreases and finally is essentially zero because hydrogen bonds do not form. However, if an adhesive capable of forming polar bonds is present, then it is observed that the final stage is effective and permanent bonds form. This is evident for the glass fibers treated with sodium silicate (curve 4) and gelatin (curve 5). Curve no. 1 is for wood pulp and curve 3 is for hydrofluoric acid-treated fibers.

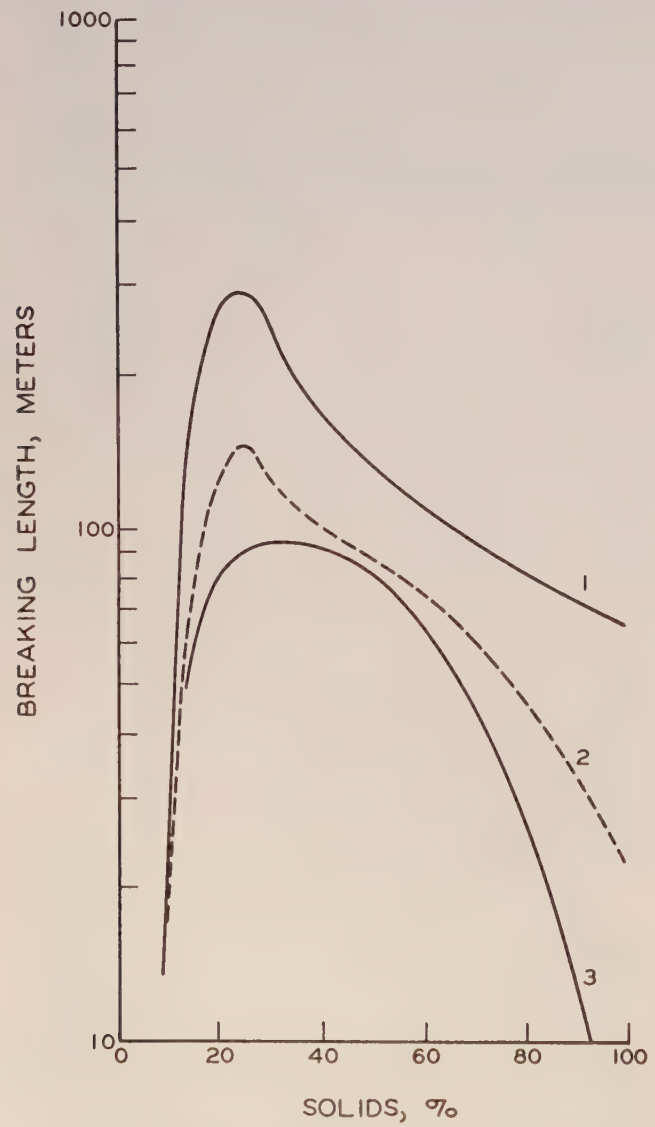

Fig. 4. Effect of reduced surface tension on strength development of glass fiber webs [From Lyne and Gallay (4)]

Similarly, Lyne and Gallay (*4*) observed that lowering of the surface tension of the water in the wet-glass web causes a decrease in the wet-web strength even in the region where hydrogen bonding does not normally occur to an appreciable extent. See Fig. 4 where curve 1 shows the glass fiber wet web at a surface tension of 72 dynes per cm.; curve 2, a surface tension of 39; curve 3, a surface tension of 33 dynes per cm.

The curves showing the effects of sodium silicate and gelatin on glass fibers illustrate the general effect of beater adhesives such as starches, gums, mucilages, and synthetic polymers. It is well known that where these materials are properly employed, paper strength is increased to an amazing extent considering the small amount of material used.

It is clear that the Campbell effect will depend upon the internal (negative) pressure of the final liquid in the paper structure. For pure and clean liquid-solid systems the experimentally measured values for internal pressure are high, but fall far short of the thermodynamically calculated values. Moreover, Briggs (*8*, *9*) has shown that contaminated systems, in which many possibilities for nucleation occur, invariably yield very low internal pressure values. It is interesting to speculate as to why the Campbell forces are so effective in a papermaking system which is so contaminated with all manner of impurities.

The Use of Beater Adhesives in Papermaking

Mechanical Preparation of Cellulose Fibers. The foregoing discussion has shown that one of the most important aspects of papermaking is the preparation of the cellulosic fibrous material in such form that intimate contact between fibers and fibrils can occur on a molecular scale. This is done by beating or refining the pulp. Alternatively, adhesives may be used.

Cellulose, beaten in the presence of water, is said to become "hydrated" although very little evidence has been found for hydration in the true chemical sense. The outstanding property of beaten cellulose fibers is their ability to form strong adhesive bonds when they are dried in contact with one another. At this point, let us examine the beating phenomenon a little closer. During the first part of the mechanical beating cycle the fibers swell and imbibe water to a considerable extent. The surface of an unbeaten fiber appears to differ significantly in composition and structure from the body of the fiber and appears to be less reactive than the underlying fiber surface. Hence, it hydrates and bonds to the surface of other fibers less readily and effectively. An unbeaten pulp thus produces a weak, poorly formed sheet. The body of the cellulose fiber is a spirally oriented fibrillar structure which is gradually loosened and unravelled as the action of the beater or refiner scuffs and rubs the overlying surface. As beating proceeds, the cellulose fibers swell considerably, the specific surface of the fiber is increased, and the fibers become more flexible as they are fully plasticized in water. All of these factors lead to greater area and intimacy of bonding between fibrils and other cellulosic fibers when the sheet is formed, pressed, and dried. This increased bonding produces a stronger paper, as indicated by strength tests such as bursting

Table I. Estimated Consumption of Some Chemical Additives by the Paper Industry

Chemical additive	*Uses*	*Annual amount used, tons*
Starches[a] (includes corn, potato, tapioca, wheat)	Improved paper strength, surface sizing, coating, laminating, corrugating	580,000
Natural gums[b] (guar and locust bean)	Improved paper strength, fiber deflocculation	7,000
Casein[c]	Paper coating	28,000
Animal glue[c]	Surface sizing	20,000
Rosin[c]	Internal sizing	150,000
Urea-formaldehyde resin[b]	Wet strength	13,000
Melamine-formaldehyde resin[b]	Wet strength	5,000
Polyamide resin[b]	Wet strength, filler retention	3,000
Waxes[c]	Sizing, coating	95,000
Vinyl resins[a]	Coating	32,000
Styrene resins[a]	Coating	30,000
Acrylic resins[c]	Coating	300
Defoamers[c]	Combatting foam	8,000
Clay (Kaolin)[d]	Coating, filling	1,000,000
Titanium dioxide[c]	Coating, filling	53,000
Calcium carbonate[e]	Coating, filling	134,000
Dyes and colored pigments[c]	Coloring	7,800
Slimacides[c]	Prevention of slime	5,800
Surface-active agents[c]	Wetting, absorbency, felt washing	17,500

[a] Estimated U. S. Tariff Commission Reports, March, 1960.
[b] Estimated by supplier.
[c] Paper Trade Journal report. "Market for Chemicals in the Pulp and Paper Industry, 1960," 1959.
[d] U. S. Bureau of Mines.
[e] Paper Coating Pigments. TAPPI Monograph Series, No. 20, p. 104.

strength, tensile strength, and folding endurance. The tearing strength, on the other hand, decreases with improved bonding. If the beating action is severe during the early stages of the operation, the fiber length may be shortened and lower maximum strength may result. In any event, if the beating action is continued too long, lower strength will be obtained in the final paper.

A further reason for beating and refining papermaking pulps is to actually shorten the average fiber length in order to decrease their tendency to flocculate or clot together. A beaten pulp will give better fiber distribution, and a better-formed sheet of paper on a paper machine. More will be said of this later on.

Although paper made from beaten stock may be stronger and somewhat better formed, it is clear that mechanical beating and refining are detrimental to many other desirable properties in paper. For example, paper made from mechanically beaten pulp is formed more slowly on the wire, it shrinks more upon drying, becomes more dense, more translucent, less opaque, less compressible, and less oil receptive. Also, such paper has a greater hygroexpansivity, and a greater tendency to curl and cockle. All of these are undesirable properties for many end uses of papers, for example, printing. Furthermore, the beating process is costly in terms of the power required. Thus, it is apparent that although beating and refining are necessary in many papermaking operations, these processes are costly and have certain disadvantages. For these reasons, papermakers have long sought a means of "hydrating" cellulose fibers by chemical rather than mechanical methods—that is to say, a material has been sought which will impart to the surface of relatively unbeaten cellulose fibers colloidal characteristics similar to those provided by mechanical beating. These materials are now called beater adhesives.

Beater adhesives, sometimes called wet-end or headbox adhesives, are materials which are added to the papermaking furnish prior to sheet formation for the primary purpose of improving strength properties. This definition distinguishes between beater adhesives and the term beater additives, which may include waxes, rosin, dyes, alum, fillers and other pigments, antifoams, pitch-control agents, and almost any other material which is added to the furnish prior to sheet formation. It should be pointed out that beater adhesives are not necessarily added to the beaters. As a matter of fact, while this is one of the more convenient points of addition, it is often not the best. See Jayne, Tongren, and Jackson (*10*), Swanson (*1*), and Cushing and Schuman (*11*) for reviews on beater adhesives.

Reasons for the Use of Beater Adhesives. Beater adhesives are used primarily for improving bonding strength between papermaking fibers. However, this benefit may be utilized in various ways, among which are the following:

1. The improvement of bursting and tensile strengths and folding endurance, as well as tearing strength, by the addition of a small percentage of the beater adhesive directly to the refined pulp.
2. Utilization of higher percentage of short-fibered pulps and pigment fillers at constant sheet strength.
3. Decreased refining or power requirements.
4. Increased mill capacity by speeding up pulp refining.
5. Increased production by increasing machine speed through faster draining on the wire.
6. Attainment of better fiber distribution or sheet formation through the use of beater adhesives.
7. Attainment of combinations of properties otherwise difficult to obtain in a given furnish. For example, a combination of high strength and high porosity in paper is uncommon except where beater adhesives are employed.
8. The improvement of wet strength through the addition of resins or other beater adhesives.

Materials Used as Beater Adhesives. A great many materials are used as beater adhesives by the paper industry both in the United States and abroad. Among these materials are the following:

1. Starches and chemically modified starches obtained from corn, potatoes, tapioca, and wheat.
2. Gums and mucilages obtained from guar, locust bean, karaya, okra, and others. Numerous products comprised of these materials are sold by several companies under trade names such as Lycoid, Jaguar (Stein, Hall & Co., Inc.), Mannogal, Stargum (Morningstar-Paisley, Inc.), Guartec, Mulgum (General Mills, Inc.), and Burtonite No. 7 (Burtonite Co.).
3. Modified celluloses such as methylcellulose, carboxymethylcellulose, and hydroxyethylcellulose are supplied to the industry by the du Pont Co., Hercules Powder Co., Wyandotte Chemical Corp., and others.
4. Synthetic polymers and resins such as the polyacrylamides and polyamides are used for improving dry-strength properties and urea-formaldehyde and melamine-formaldehyde polymers and copolymers for imparting wet-strength properties in papers. Phenol-formaldehyde resins are used for wet and dry strength improvements. Polyethyleneimine has also aroused considerable interest as a wet-strength resin but is used at the present time only in Europe. Other synthetic polymers of potential interest in this field are polyvinyl pyrolidone, polyvinyl acetate, polyvinyl pyridines, and their copolymers.
6. Hemicelluloses are important potential materials for beater adhesives. Although no company supplies isolated hemicelluloses to the paper industry for this purpose, they may be obtained from numerous agricultural residues and certain pulping operations. Moreover, the solubilization followed by readsorption of such polymers on fiber surfaces during alkaline pulping of of woods lead one to believe that hemicelluloses may behave as beater adhesives in many kraft pulps (*56*).

Papermakers are becoming increasingly aware of the potentialities and advantages of using beater adhesives in paper and board manufacture. Many new materials have been suggested for use in recent years and the technology of their use has grown enormously. It appears that the industry is getting closer to the often wistfully expressed goal of "chemical beating" or "pouring hydration out of a barrel." Actually, until recently, we were only relearning and extending some of the ancient art in this field. The Oriental countries have used certain gums and mucilages for many years to improve formation and bonding strength in their long-fibered papers.

The Use of Beater Starches in Papermaking. It is interesting to note, that starches were used for bonding and sizing papyrus as early as 3500 B.C., and have been used off and on in papermaking for the last 2000 years. In spite of this, the technology of the use of starch in the paper industry has developed rather slowly over the past 30 years. In the past, fad, fancy, and sometimes prejudice have played an important role in determining the use of starch in papermaking. There was a time when papermakers held the opinion that starch was used only when the beater man had failed to make a good pulp. In other words, starch served to cover up his mistakes. This is certainly not true today. The use of starch in the paper industry has grown at an increasingly rapid rate until now it is one of the major raw materials for the making of many grades of paper. The estimated annual consumption of cornstarch alone is 446,000 tons, and about 138,000 tons of other starches are used. The paper industry is second only to the food industry in the consumption of starches.

Cornstarch has not always been the major starch used in the paper industry. Prior to World War II, tapioca starch, imported from the East Indies, was used almost exclusively. The principal reason for this was the generally good colloidal properties of this starch. It was easily cooked in water and the dispersions were reasonably stable. Moreover, tapioca starch possesses excellent adhesive strength as do most of the tuber starches. Only when supplies of tapioca were cut off during the war did the industry turn to corn, wheat, and potato starches as substitutes. At first these starches were quite unsatisfactory but as the industry learned through research and development how to prepare and use them properly, they were found to be excellent adhesives. Although tapioca is again available, it has never regained this large market in the paper industry.

Starch is used in papermaking for two principal reasons: (1) to increase the strength properties such as bursting strength, folding endurance, and tensile strength, and (2) to supplement the beating operation. This is shown in Fig. 5. There are also several tangible reasons for the use of starch, such as improvement of erasure, decreasing surface fuzz, prevention of filler dusting, impartment of increased rattle, and with some starches, betterment of sizing. Numerous investigators have studied the use of starch in papermaking. Among these may be mentioned Casey (*12*), Rowland (*13*), Cobb and co-workers (*14*), Houtz (*15*), Kerr (*16*), and many others.

The easiest method of applying starch to paper is at the beater or wet end of the machine prior to sheet formation. When added here, the starch is distributed more or less uniformly throughout the sheet and builds internal strength. Usually, unmodified pearl starch is used and for this purpose it is cooked and added to the pulp after the rosin size but before the alum. The cooking operation consists of suspending the starch in cold water at about 5 to 8% concentration and injecting live steam until the temperature reaches 87 to 95°C., depending upon the kind of starch being used.

The cooking temperature is quite important when the optimum results from starch are desired. Probably more failures of starch occur because of faulty cooking than for any other reason. If the temperature is not high enough the starch granules merely swell without bursting; according to Rowland (*13*) when these granules come in contact with the relatively cold beater water, they shrink and become very tough and resistant. Such undispersed starch gives very little strength to the majority of papers. The bursting strength may be improved somewhat but the folding endurance little or not at all. On the other hand, too high a cooking temperature for too long a time disperses and degrades the starch excessively, and thereby lowers the potential strength-imparting properties because less starch is retained in the sheet when it is formed on the wire.

Houtz (*15*) studied the optimum cooking conditions for various starches by means of a consistometer and the soap-starch complex. [See Heald (*17*) for studies of the soap-starch complex.] Houtz assumed that the condition of maximum colloidality of the starch was that point at which the cooked starch gave the maximum increase in viscosity with soap. He found that this point of maximum viscosity gave a starch which imparted the highest improvements in bursting and tensile strengths and folding endurance. Marked differences were also noted between tapioca, corn, and potato starches and Houtz was able to correlate these differences with differences in average molecular weight of the starches.

Casey (*12*) studied the degree of cooking of a starch with respect to the density of the paper being made. He found that somewhat undercooked starch (judged by the above standards) gave better strength improvements in very low density papers than a well-dispersed starch. This behavior was attributed to the ability of the swollen granules of starch to bridge the spaces between fibers. On the other hand, high-density papers wherein the proportion of fiber-fiber bonded area is large, showed better strength improvements when a fully dispersed starch was employed.

Action of Refiners on Starch. If a considerable amount of refining of pulp is done in the jordan or a similar type of refiner, following the beating operation, the beneficial effect of the starch is often destroyed and very little improvement in strength properties will be obtained. Several remedies for this have been suggested. Among these are the following:

1. The starch may be toughened during its manufacture or during the cooking process by reaction of the starch with a small quantity of an aldehyde and acid, according to the patent of Rowland and Bauer (*18*).

2. Starches which are more resistant to mechanical action such as wheat starch may be used.

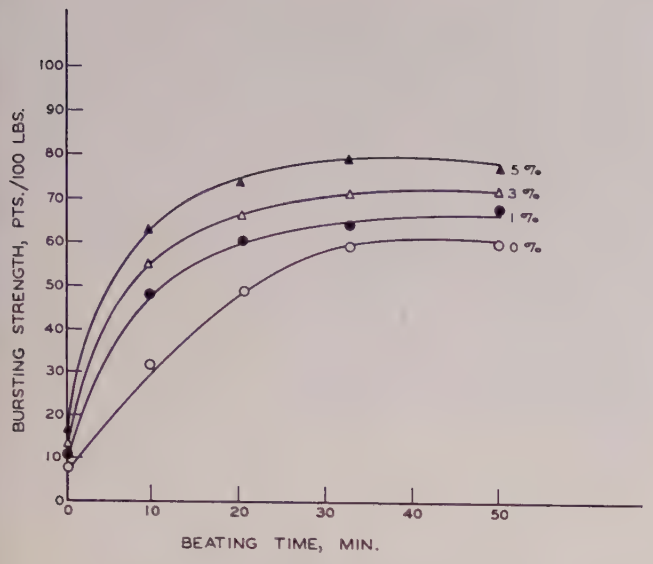

Fig. 5. The effect of cooked cornstarch on the bursting strength of coniferous bleached sulfite

3. The cooked starch may be added at the jordan outlet, the fan pump, or consistency regulator after the refining is completed.

Addition of Dry, Uncooked Starch. In spite of the fact that properly cooked starch gives the best results, some paper mills still add dry, unmodified starch to the pulp stock and depend upon the moisture in the sheet and the heat of the driers to accomplish the cooking. These results are realized to some extent only on heavier weight papers and paperboards and in these cases prior cooking will often give significantly better results.

Cold Water-Soluble Starches. The starch manufacturers have recognized the nuisance of cooking starch and have developed pregelatinized cold water-soluble starches which may be added to the beater as dry powders. Many of these products are only partially successful because of retrogradation of the starch during storage. However, borax-treated potato starches appear to be outstandingly good as regards storage and cold-water dispersibility.

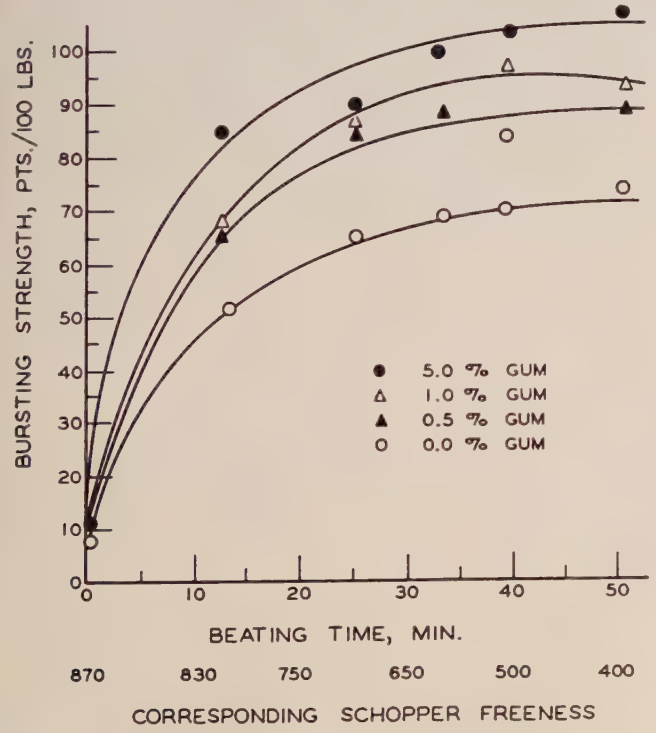

Fig. 6. The effect of beating and locust bean gum on the bursting strength of coniferous sulfite pulp handsheets

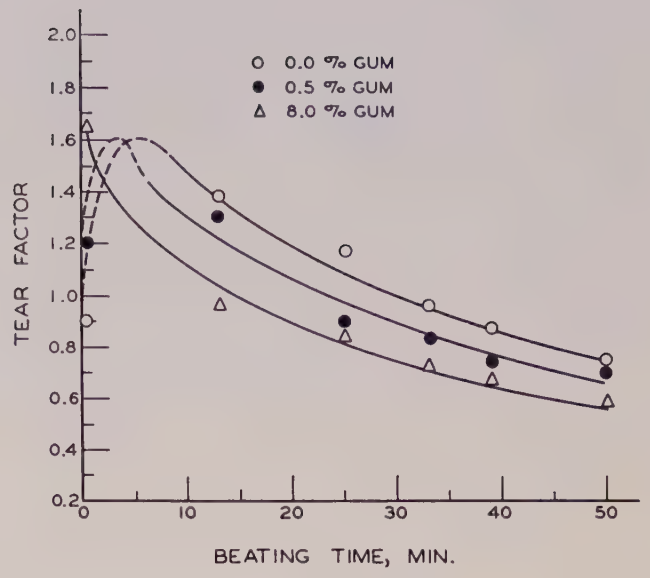

Fig. 7. The effect of beating and locust bean gum on the tear factor

Gums and Mucilages. Although starches are good adhesives, their use for supplementing the beating operation is limited because less highly beaten cellulose fibers flocculate to a greater extent and produce poor sheet formation. Therefore, better adhesives have been sought which would disperse rather than flocculate the fibers.

Some years ago, workers at The Institute of Paper Chemistry became interested in the properties of certain gums and mucilages which could be added to the papermaking system. In particular, it was found that locust bean gum was outstanding for producing strength and formation improvements in various papers. A

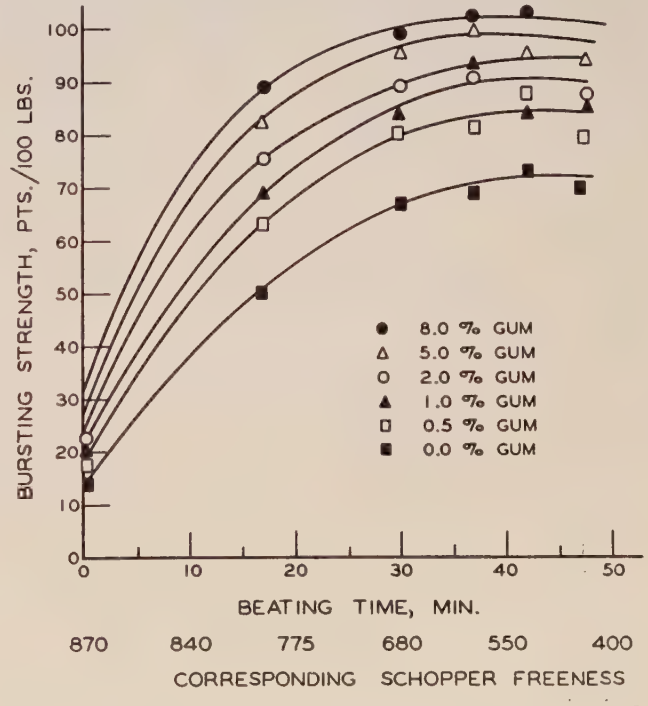

Fig. 8. The effect of guar gum on the bursting strength of coniferous sulfite pulp handsheets

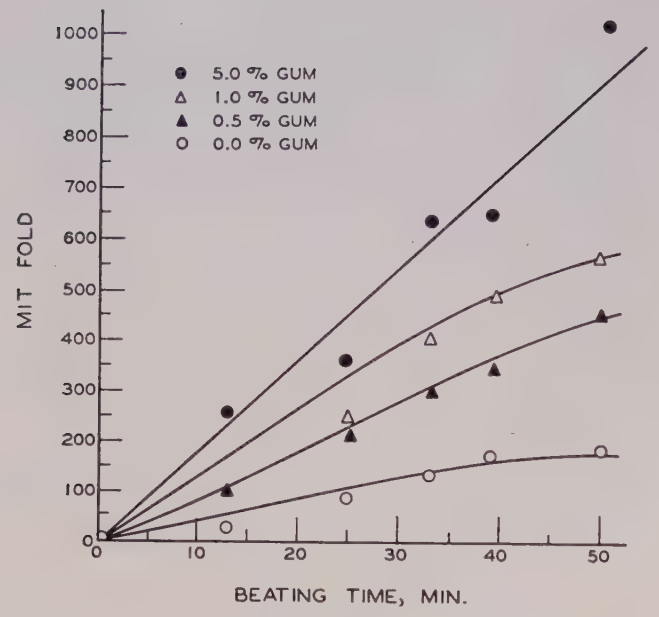

Fig. 9. The effect of beating and locust bean gum on the folding endurance

further investigation in the laboratory and mill-scale trials confirmed the superior results and many papermakers became interested. About that time World War II closed off the supply of imported locust bean gum. A large-scale project was then initiated at the Institute to find a domestic substitute. This work resulted in the development of guar gum, a mannogalactan similar to locust bean gum in chemical composition and papermaking properties. This development has been described by Rowland (*19*). The mannogalactan gums are, by far, the most important gums used by the paper industry. The total annual consumption in the United States exceeds 14,000,000 lb. and appears to be increasing.

Guar and locust bean gums possess similar chemical compositions and structures. Guar is approximately 60% mannan and 40% galactan, whereas, locust bean

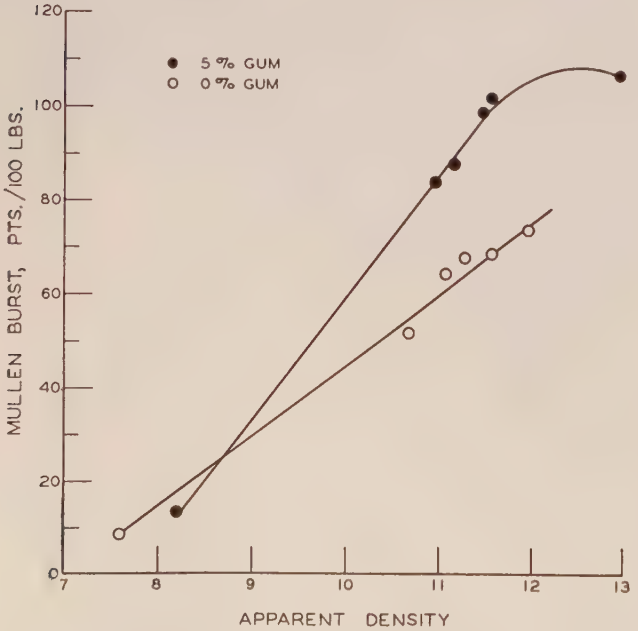

Fig. 10. The effect of locust bean gum upon the relationship between apparent density and bursting strength of coniferous sulfite pulp handsheets

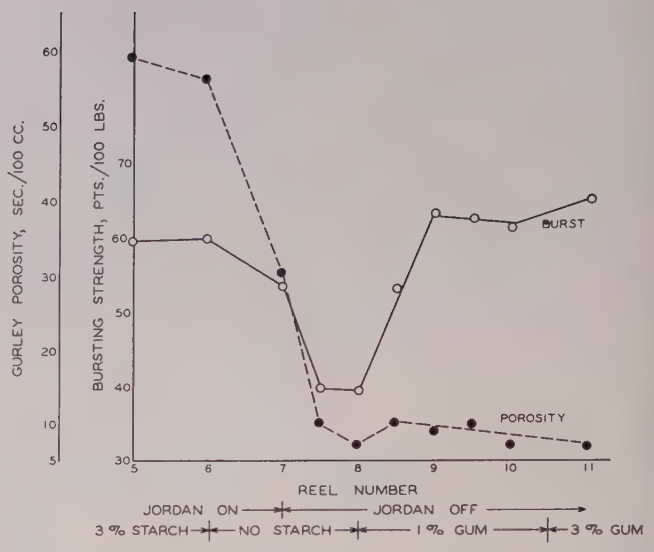

Fig. 11. The effect of locust bean gum on the bursting strength and Gurley porosity of an unrefined sulfite-soda furnish

gum has a ratio of 80:20 mannan to galactan, respectively. Both gums are high polymers consisting of straight mannan chains having beta-1,4 mannoside linkages and side units of galactan bonded to mannose by alpha-1,6 linkages. The chemical data indicate that locust bean gum has a single galactan unit on every fourth mannan unit. Guar gum has a single galactan unit on every second mannan unit. The beta-1,4 mannoside linkage in the straight chain produces a more rigid, rodlike molecule resembling in some respects the cellulose molecule. This character is distinctly different from the very flexible, coiled molecules of starch amylose and amylopectin whose anhydroglucose repeating units are connected predominantly by alpha-1,4 linkages.

The mannogalactan gums swell strongly and disperse in water to form very viscous solutions at low concentrations. The structure and chemical composition of the polymers provide efficient hydrogen bonding. Such bonding is manifested in the rapid adsorption of the polymer from dilute solutions by cellulose fiber surfaces and strong adhesion produced between such fibers when they are dried. These gums not only give larger strength improvements than beater starches but also

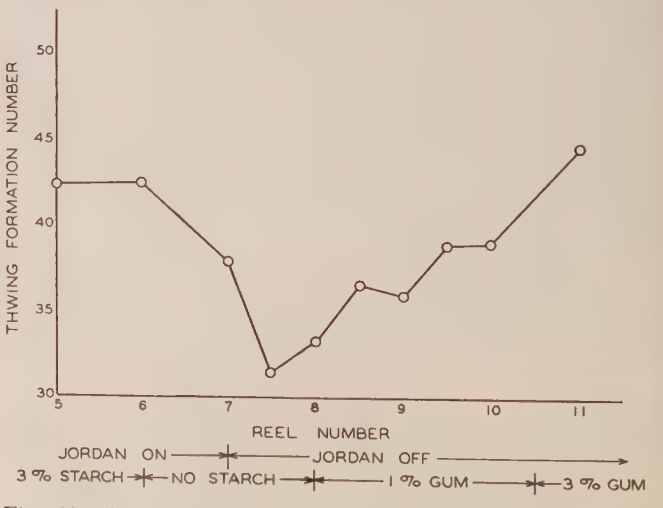

Fig. 12. The effect of locust bean gum on the Thwing formation of an unrefined sulfite-soda furnish

give good results on unbleached kraft pulps, upon which starches may not be particularly effective.

The results of an extensive handsheet study and commercial and experimental machine study of the effects of locust bean and guar gum on paper properties has been published by Swanson (*20*). Estimates of the results to be expected from the commercial use of such materials under ideal conditions can be obtained from these data. Some of the data are reproduced in Figs. 6 through 12. These data show that the addition of 0.5% of dispersed locust bean gum or guar gum (based on the weight of pulp) to a coniferous bleached sulfite pulp which had been beaten for 15 min., gave handsheets of the same bursting strength as that of the pulp which had been beaten for 50 min. This represents a reduction of 70% of the beating time and an increase in bursting strength of 32% over the original pulp. Similarly, 1 and 5% of the locust bean gum gave 40 and 60% increases in bursting strength, respectively. Guar gum products were shown to give similar results to those of locust bean gum products. Large increases in tensile strength and folding endurance were also evident in these same papers.

The effect of the gums on the tear factor was shown to be the same as increasing the degree of beating of the pulp, that is, improved fiber bonding decreased the tear factor. It is apparent, however, that where mechanical beating is reduced and the gum is used to attain a desired bursting strength, appreciably higher tear may be obtained than could be realized by mechanical beating to the same desired strength. Presumably, this improved tear results from the longer fiber length. It is also evident that reduction in mechanical refining and improvement of the bonding strength through addition of gum produces appreciable increases in porosity, drainage rate, and opacity, as well as decreases in apparent density, and hygroexpansivity. It is interesting to note that when the gums are added to unbeaten pulp, little improvement in strength properties resulted. It appears to be necessary to roughen the surface or to increase the specific surface of the fibers before the gum is retained. Comparisons of starches and locust bean gum in commercial trials and on an experimental paper machine, showed the unmistakable superior bonding strength of the gums.

The Use of Starch-Gum Mixtures. At times, because of limited supplies of gums or economic factors, starch-gum mixtures have been utilized as beater adhesives in papermaking. In some cases it has been found that a synergistic effect exists when the gum and starch (in a ratio of 40:60 by weight) are cooked together before addition to pulp. Goldstein (*21*) has suggested that the highly branched amylopectin fraction of starch allows better distribution of the more reactive gum molecules within the pulp suspension. Cushing (*22*) investigated the synergistic effect in both the laboratory and in commercial trials. His work showed that the effect may be caused by increased retention of the amylose component of whole starch. Cushing suggests that although colloidally dispersed amylose can be sorbed on the surface of cellulose fibers in any of its three equilibrium forms (helix, extended or linear, or retrograded) it may be expected that most rapid sorption occurs from the extended form. Iodine complex data indicated that the presence of mannogalactan molecules during dispersion of the starch stabilizes the linear or extended configuration of amylose. Under this condition the ability of amylose to shift to the inert, highly retrograded or crystalline form, or into the helical configuration is markedly reduced. Cushing further suggests that the preferred orientation insures higher efficiencies as to strength and surface improvements when gums and starches are used in combination.

The Effects of Gums and Mucilages on Fiber Flocculation. From one standpoint the system represented by cellulose fibers suspended in water is an unstable colloidal suspension. In other words, the cellulose fibers tend to flocculate as a function of time. A high degree of fiber flocculation at the instant the sheet is formed on a wire is registered in the final sheet as poor formation and poor bond distribution. Generally speaking, this is an undesirable sheet characteristic because of the relatively weak character of such papers. Numerous factors affect the rate of fiber flocculation such as the type of pulp, fiber length, temperature and viscosity of the water, the type of beating, the method of forming the sheet, the presence of various ions, particularly multivalent ions, the presence of flocculated materials, such as alumina, pigments, etc., and the presence of gums and mucilages, such as locust bean gum, guar gum, and certain others which will be mentioned below. The effects of many of these variables upon fiber flocculation have been studied by Wollwage (*23*) and Erspamer (*24*).

It is clear that where beater adhesives, such as locust bean and guar gums are to be used for improving bonding under conditions of reduced mechanical beating, the gum or mucilage should function in a manner which will slow up the rate of fiber flocculation. Otherwise the longer average fiber length will cause greater flocculation of the fibers and poor sheet formation, thereby reducing the effectiveness of the beater adhesive. The effectiveness of locust bean gum on the formation number of an unbeaten sulfite-soda paper is shown in Fig. 12. Locust bean and guar gums are quite effective deflocculating agents for ordinary long-fibered pulps such as coniferous sulfite or coniferous sulfate pulps. However, where extraordinarily long-fibered pulps such as those from manila are used, these gums appear to be inadequate in certain respects. For such pulps, deacetylated karaya gum and certain extracts such as those obtained from *Hibiscus manihot* are necessary. It is found that the effectiveness of these latter materials depends on a peculiar rheological characteristic possessed by their dispersions in water. This characteristic is referred to as "stringiness," "ropiness" or, more elegantly "pituitousness." The latter term is defined as, full of, resembling, or due to, mucous. The greater the degree of pituitousness possessed by an aqueous dispersion of the gum or mucilage in water, the greater will be the deflocculation quality of this dispersion on very long-fibered pulps. At the present time karaya gum is the only commercial material available to the paper industry for the extraordinarily long-fibered pulps. Those companies which manufacture papers such as stencil, duplicating papers, tea bag papers, and certain electrical insulating papers, where uniform fiber distribution and very high strength are important find it necessary to use a deflocculant of this type. Because the karaya gum is imported from

India and Pakistan and the quality and price are quite variable, these paper manufacturers are very much interested in obtaining a domestic substitute for deacetylated karaya gum. It is expected that domestic okra (*Hibiscus esculentus*), certain synthetic polymers, and cross-linked carboxymethylcellulose preparations may fulfill this need within the near future. Further suggested uses of beater adhesives and a review of the literature through December, 1955, is presented elsewhere (*2*).

Fundamental Studies on Beater Adhesives

It is clear that the use of beater adhesive polymers is of major importance to modern papermaking. The addition of small amounts of suitable polymers to the fiber-water system will, under suitable conditions, improve fiber dispersion, enhance fiber bonding, and produce notable improvements in both wet strength and dry strength of paper and board. Where these beater adhesives are used, excessive mechanical damage to the fibers is obviated and in addition to improvements in strength, papers can be made which have higher porosity, higher opacity, better formation, and better compressibility for printing. Furthermore, with such strength improvements, higher percentages of fillers and lower quality pulps may be used.

Experience shows that some polymers are more efficient beater adhesives than others for improving strength or fiber distribution. Some beater adhesives perform well in the laboratory but erratically in the paper mill. Still other polymers, known to be excellent adhesives when used for tub sizing or impregnating papers and boards, are of little or no value when used as beater adhesives. Why is this so? What factors are responsible for such behavior? How do polymers improve paper strength? What makes one polymer a better beater adhesive than another? Why are some polymers directly substantive to cellulose fibers whereas others require addition of salts such as aluminum sulfate or a selected pH range in order to be effective? What are the effects of temperature, specific surface, and chemical composition of the pulps and why?

The answers to such questions are obtained only through prudent basic research on the polymer-water-cellulose fiber system under carefully controlled conditions. Let us consider then, the recent research which may answer some of these questions. First, how do beater adhesives improve the strength of paper?

The Mechanism of Improvement of Paper Strength with Beater Adhesives. A great deal of interest exists in the reasons for improvement of paper strength when beater adhesives are used. One of the most important studies in this field is that of Leech (*25*) who investigated the reasons for increase in paper strength when locust bean gum is used as a beater adhesive. He suggested that the strength of paper depends mainly upon four factors: the strength of fibers, the strength of fiber-to-fiber bond, the number of bonds (bonded area), and the distribution of bonds as indicated by the fiber distribution or sheet formation. He further suggested that beater adhesives, provided they are retained by the fiber, must increase the strength of paper by affecting one or more of these four factors. He utilized the optical method of Parsons (*26*) and Ratliff (*27*) for bonded area, The Institute of Paper Chemistry bonding strength tester for bond strength (*28*), the Thwing formation tester for bond distribution, and the zero-span tensile test for fiber strength. With this information he was able to separate and assign a value to each of the contributions to the overall improvement in strength. The contribution of each factor was as follows: increased bonded area, 15%, improved formation, 25%, increased bonding strength, 60%, increased fiber strength, 0%. At the present time we have not yet determined whether the greater bonding strength results from greater intrinsic bond strength between gum molecules, greater bond flexibility, or a greater number of bonds per unit area of bond.

The Mechanism of Wet-Strength Development in Paper. Further information concerning the nature of adhesive bonding in paper has been obtained through studies of wet-strength resins. Britt (*79*) in the TAPPI monograph on wet strength shows that the tensile strength of papers wetted with various liquids depends upon the swelling action of the liquid. Water which promotes bonding during drying of the paper also destroys bonding when it is able to swell the fibers and the bond region. Liquids which are unable to swell the structure have little effect on strength of dry paper. A wet-strength resin, such as urea-formaldehyde or melamine-formaldehyde, which has been retained by the fibers is able, upon proper curing of the resin, to develop an appreciable strength in paper even after it is thoroughly rewetted with water. Such resins are now widely used in the paper industry for making wet-strength towels, tissues, and many other wet-strength products. Similar resins are used in the textile industry for imparting crease resistance to fabrics. Attempts to determine the nature of the reaction between the resins and cellulose have not been conclusive but they are instructive.

Steenberg (*80*) suggested that wet-strength resins decrease the hygroscopicity of the fibers. This mechanism could involve either a physical restraint on the bond region or the formation of cross links with cellulose.

Recently, Jurecic, Lindh, Church, and Stannett (*81*) studied the kinetics of wet-strength development with an unmodified urea-formaldehyde resin on unbleached kraft, cotton, cotton linters, and glass fiber papers. The activation energies for the resin cure on cellulosic fibers averaged 22.6 ± 0.8 kg.-cal. per mole compared with 23.8 ± 0.6 for glass paper. These values are in good agreement and indicate that the reaction leading to wet strength is independent of the fiber. Landes (*82*) obtained an activation energy of 11 kg.-cal. per mole for melamine-formaldehyde resin and Marder, Church, and Stannett (*83*) 23.4 kg.-cal. per mole for a phenol-formaldehyde wet-strength resin. The lower value for melamine reflects the greater ease of cure as compared with unmodified ureas and phenolics (*81*).

The values of the activation energies do not rule out covalent linkages between fibers and resin, if such reactions have lower or equal activation energies to that of the cure itself. Attempts were made by Jurecic and co-workers (*81, 84*) to determine whether or not

such links are formed. They studied the reactions of a nonpolymerizable model compound, 1,1-dimethyl-3-methylol urea, with cellulose and with alpha-methyl-glucoside and the reaction of the latter compound with urea-formaldehyde resin. Filter paper treated with 1,1-dimethyl-3-methylol urea at pH 5.0 for 5 min. and then dried and cured 4 hr. at 140°C. did not develop wet strength, and more than 95% of the compound could be extracted by water or dilute caustic.

This shows that little, if any, of the compound reacted with components of the fiber. Heating alpha-methyl-glucoside with either an aqueous solution of urea-formaldehyde resin or the model compound did not change the optical rotation of the mixture. When the glucoside was heated in urea-formaldehyde resin solution in an open tube (thereby allowing water of condensation to escape) it was found that the glucoside could be quantitatively recovered by extracting the cross-linked resin with cold water (*84*). This experiment excludes the possibility of bond formation between glucoside and the resin during polymerization of the latter and suggests that carbohydrate hydroxyls do not form ether links with the urea-formaldehyde resin. It does not preclude, however, reactions of resin with minor constituents of the pulp such as carboxyl and aldehyde groups.

Why then, if curing of the resin itself is the governing reaction, do papers containing the same amount of resin yield widely different wet-strength values? Steenberg (*80*) and Fineman (*85*) have suggested that the resin diffuses into the accessible parts of the fibers and restricts swelling or wetting. Thus, the wet strength may result more from protection of existing interfiber hydrogen bonds than from resin-fiber bonds *per se*. Fineman's work (*85*) supports this idea. He showed that the wet strength of a pulp is drastically reduced when the hemicelluloses are removed. However, his data show that the ratio of wet to dry strength remains similar in all cases. When starch was introduced to the low hemicellulose paper followed by resin treatment, high wet strength returned.

Jurecic and co-workers (*81*) point out that partial diffusion of resin into fibers should lead to stronger resin-fiber anchoring. Simultaneously, the actual wet strengthening would be due to the cross-linking or water insolubilization of the resin, partly in and partly outside the cell walls and as such, would be kinetically the same as the cross linking of the resin itself which is the only reaction that can occur with glass fiber papers. These workers found that curing of resin-treated unbleached kraft, cotton, and filter papers at elevated temperatures (120°C.) did not increase the dry tensile strength of the kraft paper but did increase the dry strength of cotton and filter papers. Their data indicate that no significant number of effective resin to fiber bonds exist in kraft paper because if this had occurred the dry strength would have been improved. However, in the case of filter paper, resin to fiber bonds appear to be formed.

Moisture sorption data on cured and uncured resin-treated papers show a marked decrease in water sorption of the wet-strength papers. Jurecic, *et al.* (*81*), point out that their saturation procedure employed for incorporating the lower molecular weight resin into their papers may permit penetration of the whole amorphous part of the fiber. Steenberg (*80*) suggested that the beater addition technique probably permitted only surface deposition of the resins on the fibers. The recent fiber-staining work of Kurath, Chu, and Swanson (*60*) and Becher, Hoffman, and Swanson (*62*) shows little penetration of the fiber by resin over the concentration range commonly employed in practice.

Retention of Polymers by Cellulose Fibers. Next, let us examine the matter of retention of polymers by the cellulose fibers. It is absolutely necessary to have accurate information on retention before an understanding of beater additives can be obtained.

Examination of the literature discloses that a majority of studies on beater adhesives have been based upon the amount of polymer *added* to the pulp rather than the amount which is *retained* by the fibers. It is obvious that an effective polymer must be retained in the paper if it is to improve fiber bonding. An outstanding illustration of the point is polyvinyl alcohol. This polymer is one of the strongest adhesives when used for tub sizing or impregnating papers, but when added to the fiber-water slurry before sheet formation the strength of the subsequent paper is unaffected because the polyvinyl alcohol passes into the white water. No significant amount of the polymer is retained by the fibers. On the other hand, there is reason to believe that a high degree of retention of a polymer is not the only requirement for an efficient beater adhesive. For example, under certain conditions in the presence of alum, carboxymethylcellulose is retained very well without any benefit to strength. At lower alum concentrations and higher pH values, the same carboxymethylcellulose improves fiber bonding considerably.

The Retention of Starch and Its Principal Polymers Amylose and Amylopectin. A considerable amount of speculation has been made regarding the mechanism of retention of starch in paper. The *percentage* retention may be important under certain conditions but with modern day recirculating white water systems, it is commonly believed that the concentration of starch eventually reaches a level wherein the amount of starch in the final sheet is approximately that which is added. Moreover, the mechanism or manner in which the starch is retained in the sheet is probably of greater importance than the percentage retention. Studies in this field have been limited until comparatively recently because of a lack of accurate methods for determinations of starch in paper. For determination of starch in papers see TAPPI Standard T 419 m-45 and Browning, Bublitz, and Baker (*29*).

Most of the suggested theories of the retention of starch in paper fall into one or more of the following categories:

1. Starch is retained in paper by a filtering action during sheet formation on the wire [Strasser (*30*), Steffens (*31*)].
2. Starch is flocculated by the alum and is sorbed by the positively charged alumina and cemented to the fiber. [See Rowland (*13*).]
3. Starch is directly sorbed by cellulose fibers.

Under ordinary papermaking conditions it appears that all of these mechanisms function to a degree.

Several processes have been proposed whereby distinct advantages with regard to retention and starch

effectiveness are obtained. Kesler and Black (*32*) have developed a method of precipitating starch onto the fiber by means of soaps and alum or calcium chloride. Several mills have reported favorable results with this process. Rowland (*13*) has stressed the point that the amount of starch retained is not as important as the effectiveness of the starch which is retained and its distribution through the fiber mass. In other words, a high retention retained with improperly prepared and poorly distributed starch held by filtering action alone, shows much poorer reinforcing action than less starch, properly prepared, distributed, and attached to every fiber in the furnish.

Rowland (*33*) developed a method of incorporating starch called the starch precipitation process, whereby starch is precipitated and fixed onto the fiber by means of alumina under specified conditions. Essentially, the process consists of the addition of properly cooked starch to the pulp containing the rosin size and extra alkali, followed by the addition of sufficient alum to bring the pH within the range of 5.0 to 5.2. There is very little doubt that this process is capable of superior results. Whereas normal methods of adding starch to pulp may not give significant strength increases beyond about 4% starch based on the fiber, this process continues to impart significant strength improvement at 6% starch and beyond, being limited principally by the slowness of sheet drainage developed on the wire. Furthermore, this process may be used to increase the ash content of a sheet considerably above the possible limit under normal conditions. The clay or other filler is carried along with the precipitated starch and bound more firmly in the sheet.

A number of investigators have approached the problem of starch retention and effectiveness in terms of the two principal fractions, amylose and amylopectin. Casey (*34*) indicated that fractions of starch which were predominantly amylopectin give better bursting strength increases than either whole starch or fractions which were predominantly amylose. Tanret (*35*), Pacsu and Mullen (*36*), and later Kerr and Severson (*37*) showed that amylose is adsorbed on cellulose up to approximately 1% by weight of the fiber. As better methods of separation of amylose and amylopectin became available [see T. J. Schoch (*38, 39*)] purer starch fractions could be studied. Kerr and Schink (*40*) were probably the first to determine the role in papermaking of fractions now regarded as reasonably pure. These investigators tested the effect on the bursting strength of paper when each fraction was added in the beater. They found that although the amylose was sorbed by the cellulose "almost to the anticipated limit" (1% based on the fiber) the bursting strength was not improved. The amylopectin fraction, however, was found to give much better results than the whole starch. Rosin and alum were used in sufficient quantity to give 60% retention of the amylopectin fraction in paper.

Pearl (*41*) studied the sorption and rate of sorption of the amylose fraction of starch by papermaking fibers in considerably greater detail. Contrary to previous investigators he showed that the sorption of the amylose fraction was not limited to 1% on the weight of the fibers, but depended upon the type of fiber and the degree of beating or specific surface. The rate of sorption was found to be initially high followed by a much slower rate. However, the sorption continued at the slower rate until the amylose was completely removed from the dispersion after as many as 600 hr. at 25°C. In other words, no sorption equilibrium was reached short of exhaustion of the bath under any conditions. He suggested that the mechanism of sorption is apparently a consecutive dual rate process in which the amylose is sorbed by the cellulose surface and the sorbed amylose continues to sorb additional amylose by a mechanism similar to retrogradation. Lower temperatures, higher amylose concentrations, and increase in the degree of beating of the pulp, caused an increase in the rate of sorption of amylose. Low pH values (4.0) caused much more rapid sorption than high pH values (10.4). The sorption of amylose was irreversible with regard to concentration changes. However, some reversibility at higher temperatures and higher pH values was evident. Pearl also showed that the amylopectin (branched) fraction of starch is also sorbed by cellulose, but the rate appears to be much slower than for amylose and the quantity of sorbed polymer reaches a limiting value.

Contrary to the results of Kerr and Schink (*40*) Pearl's handsheet studies indicated that strength improved with the amount of amylose sorbed. Bursting strength increases of 60 to 75% over the original pulp were obtained for a retention of 5% of amylose. The bursting strength of amylopectin-treated handsheets at 0.8% sorption was significantly greater (40% better than the control) than that of handsheets containing an equal amount of amylose (20% better than the control).

The results of Pearl also have some practical significance. His data indicate that starch should be added to the papermaking system as far back as possible in order to give the fractions of starch a maximum time for adsorption on the fiber. This must be a compromise, however, with the deleterious action of the refiners on the starch. Low temperatures will also increase the rate of sorption very much and the advantage of this may be realized particularly in the winter time when the water temperature is low. Because the sorption is only partially reversible at higher temperatures, warmer conditions later in the mill will not vitiate the increased sorption at the lower temperatures.

Cushing (*11*) showed that the percentage of the added starch which was retained was essentially the same at all levels of addition for unmodified, or unsubstituted starches. However, those starches to which substituents such as hydroxyethyl or chemical modification had been introduced were less well-retained the higher the degree of modification. He attributes this to a lowered tendency of the modified or substituted starches to associate with themselves or to crystallize. Further work is needed in this field, particularly on the effects of salts and modifications of the starch on the rate of sorption.

The need for improved retention of starches has been recognized by the starch producers. Recently, chemically modified starches (Cato 4 and Cato 8, National Starch Co.) which appear to be cationically charged have been offered to the paper industry. These products are distinctly superior beater adhesives as

compared with unmodified starches. Furthermore, they function as retention aids for fillers, pigments, and other finely divided materials which may be present in the papermaking system.

The Retention of Other Polysaccharide Polymers by Cellulose Fibers. Determination of the retention of starches and their principal polymers is comparatively straightforward because of their characteristic interactions with iodine. Also, nitrogen-containing polymers such as urea-formaldehyde and melamine-formaldehyde can be determined readily and accurately in paper by suitably modified Kjeldahl methods. However, retention of many other polysaccharide polymers such as the mannogalactan gums, hemicelluloses, chemically modified celluloses (methyl, ethyl, or carboxymethylcellulose), and other neutral polymers present greater analytical problems. Considerable attention has been given to this important problem in recent years.

Shriver, Webb, and Swanson (*42*) suggested two methods for measuring the retention of locust bean gum and methylcellulose. Their anthrone method involves an analysis of the carbohydrate content of the filtered white water before and after sorption of the additive. Their viscosity method involves measurement of the viscosity of the white water before and after sorption. The difference in both methods is related to the amount of carbohydrate sorbed by the pulp. However, the results of these investigators showed that the differential viscosity method gives retention values which are about one and one half to two times the values obtained by the anthrone method.

These methods were used by Shriver (*43*) for study of the sorption of water-soluble cellulose ethers by cotton linters, bleached and unbleached sulfite, and bleached and unbleached kraft pulps. Sorption required 100 to 180 hr. for completion, and was found to increase three to fourfold from unbeaten to well-beaten pulps. Sorptions varied from 0.1 to 7.0 g. per 100 g. of pulp. Bleached sulfite had the greatest sorptivity, followed closely by bleached kraft and unbleached sulfite, which were about equal. Cotton linters and unbleached kraft showed the lowest sorptivity. Molecular weight, over the range studied, of 24,000 to 126,000, had no effect on sorption. Rosin and alum in ordinary amounts also had no appreciable effect. However, larger quantities of alum alone greatly increased the sorption. The sorption was found to be irreversible with respect to isothermal changes in concentration and a hysteresis effect was noted for temperature changes. Increases in temperature caused an increase in sorption. The mechanism of sorption appears to involve a combination of gelation and true adsorption. The heat of retention was determined to be 21,500 cal. per mole (endothermic), the heat of gelation 29,700 cal. per mole (endothermic), and the heat of adsorption, 8200 cal. per mole (exothermic). A mechanism of sorption involving formation of multiple hydrogen bonds is presented.

Keen and Opie (*44*) also employed a differential colorimetric technique in their study of the sorption of guar gum on boxboard and bleached kraft pulps. They found that gum sorption was only slightly dependent on gum concentration and there appeared to be a definite limit to the quantity of guar sorbed at a given pulp surface area. This method was employed also by Karna and Nordman (*45*) for determination of retention of locust bean and guar gums. The latter workers found locust bean gum more effective than guar and these gums were more effective on sulfite and bleached pulps than on sulfate and unbleached pulps. Higher lignin content decreased retention of the gum.

One factor which is not often taken into consideration in studies where carbohydrate analyses are employed is the change in the value of the cellulose control with change in gum concentration (*42*). At higher concentrations of gum more cellulose fines are peptized and pass through filters. Thus, the apparent carbohydrate present may be high.

Gruenhut (*46*) studied the mechanism of retention of mannogalactan gums by means of a differential viscosity method. She suggested that the unmodified gums were retained by adsorption on the fiber surface by hydrogen bonding. Retention of the unmodified gums depends upon the concentration but the retention of gums modified with borate ion is, within certain limits, independent of the gum concentration.

Leech (*47*) developed a chromatographic method for the determination of locust bean gum in paper by analysis of sugar units. The steps involve hydrolysis of the gum-treated paper with dilute sulfurous acid solution, recovery of sugars, separation of the sugars by means of paper partition chromatography, and determination of the sugars by oxidation with sodium periodate. This technique was used in his study of the reasons for improvement in strength when beater adhesives are used in papermaking (*48*). Although somewhat time-consuming, this is probably one of the most accurate methods for sorption studies on pulps which do not themselves contain mannose or galactose.

Swanson, Becher, and Dickey (*49*) employed a radioactive tagging method to measure the sorption of locust bean gum by papermaking fibers and pulp fines. Preparation of the tagged gum was done by reacting the sodium derivative of the gum, prepared according to Gaver (*50*), with carbon-14 labeled methyl iodide. This very slightly methylated gum was then used for studies of the distribution of the gum between the paper fibers, the fines, and the white water. A thin-window Geiger-Mueller counter was used for the radiochemical measurements. Although the experiment was designed to account for all of the gum added to the system, only 75 to 85% of the gum was recovered for gum additions between 0.5 and 2.0% based on the pulp. A check of some of the same gum-treated handsheets (*51,1*) with a Bernstein-Ballentine proportional counter technique (*52*) has shown that the Geiger-Mueller thin-window method gave results which are about 15% too low. Isbell (*53*) suggested a much improved method of tagging polysaccharide molecules which in many cases will also yield a measure of the molecular weight of the polymer by radiochemical measurement.

Isbell's radiotagging method (*53*) was used by Most (*54*) in his study of the sorption of four slash pine hemicellulose fractions by bleached sulfite pulp fibers. These products are similar to those employed by Thompson, Swanson, and Wise (*55*). The polymers represent a graded series of increasing mannan and decreasing polyuronide composition. The initial rates

of sorption were high for all fractions but the rate was higher for the polymers of higher mannan and lower polyuronide contents. Sorption rates became much slower after 10 hr. but no equilibrium was reached in 10 days. Sorption was irreversible over a wide range in amount of sorbed polymer. Temperature effects were variable—higher temperature caused an increase in sorption for one fraction, a decrease for another and no affect for two other fractions. Most concluded that the retention mechanism was similar to that found for amylose by Pearl (*41*). The hemicellulose polymer deposits first on the fiber surface and then multilayer sorption of hemicellulose on hemicellulose occurs.

Yllner and Enström (*56*) studied the sorption of pentosans from birch- and sprucewood during the early stages of a kraft cook. The pentosans were sorbed from the cooking liquor on cotton, cotton linters, and bleached sulfite fibers. It is interesting that the sorption was irreversible with respect to concentration and approximately 20% of the sorbed pentosans could not be removed from the pulps by one-hour extraction with 10 to 20% caustic solutions at 20°C.

More attention should be given to the rate of sorption of polymers by cellulosic materials. Studies in this field have been hampered not only by slow development of analytical methods but also by the heterogeneity of the reactions which occur and by inadequate characterization of the polymers. Important contributions in this area have been made recently by Russo (*57*), Russo and Thode (*58*), Thode, Swanson, Kurath, and Hoffman (*59*) Kurath, Chu, and Swanson (*60*), and Becher, Hoffman, and Swanson (*62*).

Russo (*57*) studied the effects of time, concentration, temperature, degree of agitation, and pulp specific surface area on the rate of sorption of a partially methylated locust bean gum (PMG) by bleached sulfite fibers. This polymer was radioactively tagged with C^{14} by the method suggested by Swanson, Becher, and Dickey (*49*). Attempts to use Isbell's method (*53*) of end-group tagging were unsuccessful because the molecular weight was too high to yield adequate radioactive counting accuracy. The calculated average temperature coefficient for each 10°C. rise in temperature was 1.3 which suggested that a diffusional transport step was rate controlling in the overall sorption phenomenon. This concept was supported by determination of the activation energy of the process which turned out to be 4400 cal. per mole. The importance of a diffusional transport step was investigated further by a study of the effect of agitation on the sorption of the partially methylated gum. If a physical transport step is important, then agitation should reduce the resistance to molecular transfer and increase the sorption of gum. A marked dependence of sorption on the degree of agitation was found which confirmed the hypothesis. In discussing the nature of PMG sorption on sulfite fibers as interpreted from his data Russo makes the following points. The rate of PMG sorption under near infinite bath conditions is initially high, decreases very sharply, and then levels off to a much lower value. This suggests that more than one process may be involved as the sorption continues with time. Similarly, the relation between sorption rate and the *amount of* PMG retained indicates possible multilayer sorption. Conservative estimates of the size (area) of the PMG molecule [51 A × 255 A, molecular weight 310,000, see Kubal and Gralen (*61*)] show that as little as 0.5 g. per 100 g. of pulp would be sufficient to cover the surface of the pulp fibers. (Specific surface area of the pulp was 11,780 sq. cm. per g.). At a pulp consistency of 0.017% and PMG concentration of 0.1 g.p.l. this quantity of gum (0.5% based on the fibers) was sorbed in about 90 sec. Cushing and Schuman (*11*) point out that the works of Pearl (*41*), Leech (*48*), Most (*54*), and Russo (*57*) all show that in spite of the diffusion process which apparently controls the sorption rate, the early stage of the sorption is quite rapid in terms of the amount of polymer in pounds per ton of paper fibers. Russo (under somewhat different conditions than those above) showed that over 13 lb. of gum could be sorbed per ton of bleached sulfite pulp in the first minute. Cushing's work (*11*) showed that 7 to 8 lb. of starch products can be sorbed by a ton of fiber in 15 sec. (in presence of alum). There remains little doubt that multimolecular sorption of polymer occurs at longer sorption times. Russo (*57*) concluded that a transport process such as diffusion is rate determining in the overall retention phenomenon, but the sorption of the gums by the fiber surfaces is a consecutive rate process involving both deposition of gum on the fiber, and subsequent sorption of gum by the gum-fiber complex. The sorption process requires a low energy of activation and is, therefore, believed to be of the physical or Van der Waals' type. Physical dispersion forces from numerous "active centers" throughout the cellulose surface set up a force field capable of attracting and holding the gum molecule. Ultimate retention of the gum is hypothesized to occur via multiple hydrogen bonding, which produces a high degree of sorption irreversibility.

The Retention of Resin Polymers. It is interesting to note that kinetic studies on the retention of melamine-formaldehyde resin by Thode, Swanson, Kurath, and Hoffman (*59*) gave an activation energy of 5600 cal. per mole for a bleached sulfite pulp and studies on a cationic urea-formaldehyde resin by Kurath, Chu, and Swanson (*60*) gave an activation energy of 5200 cal. per mole. Becher, Hoffman, and Swanson (*62*) continued this work and showed that diffusion was also the rate-controlling step in these systems. These activation energies agree well with Russo's 4400 cal. per mole for PMG. On the other hand, Shriver obtained a heat of retention value of 21,500 cal. per mole for methylcellulose sorption. If one assumes that the activation energy must be at least this large for the retention process it would appear that the sorption of methylcellulose may involve other mechanisms. Shriver showed that retention of methylcellulose involves a heat of gelation of 29,700 cal. per mole from which a heat of adsorption of 8200 cal. per mole may be calculated. The latter value is the same order of magnitude as that found for the gum and resins and indicates that the sorption itself may involve hydrogen bonding similar to the other polymers. Further considerations of rate phenomena in resin-fiber-water systems have been presented by Thode (*63*).

The Nature of Polymer Sorption. Further basic studies in the field of adsorption of all kinds of long-chain molecules are needed. These would lead to a better understanding of the mechanism of adsorption

and adhesion of polymers to solid surfaces (*64*). Such studies are necessary for intelligent interpretation of polymer behavior in the complex papermaking white-water system.

The question of the nature of the driving force which causes sorption of the polymer is particularly intriguing. Why should such linear polymers as amylose, the mannogalactan gums, and methylcellulose be so strongly adsorbed while polyvinyl alcohol with the same propensity for hydrogen bond formation remains unadsorbed under similar conditions? Basically, it may be supposed that the driving force in any sorption depends upon the thermodynamics of the system. Experience shows that substances which are highly solvated in good solvents are less well adsorbed than materials which are poorly solvated. In polymer sorption it seems reasonable to expect that the change in free surface energy through adsorption must be greater than the free energy change which occurs from that part of the polymer which becomes desolvated upon adsorption. If it were otherwise, the process of sorption would not be spontaneous. Of course, entropy changes must also be considered in this process and little information is available on this subject. This thermodynamic hypothesis may explain why polyvinyl alcohol is not adsorbed *from solution* by fiber surfaces. Apparently, the polymer is too highly solvated. The validity of this hypothesis could be ascertained by careful study of the adsorption of polyvinyl alcohol by fibers from poorer solvents or by study of partially hydrolyzed polyvinyl acetates which are barely water dispersible. Valuable contributions to this field are the papers of Frisch, Simha, and Eirich (*65*) on the statistical mechanics of polymer adsorption and the papers of Simha, Frisch, and Eirich (*66*), and Frisch and Simha (*67*) on the adsorption of flexible macromolecules. These workers considered the formation of a polymer monolayer on a substrate from dilute solution. They suggest that because of chain flexibility and possible coiling, deposition of whole chains is unlikely. Rather, short sequences or segments of chains are adsorbed and these segments are linked by bridges or loops extending into the solution. The free energy changes arising from mixing with active sites on the surface and with solvent are obtained from the respective frequency distributions. For very large chains, the heat of adsorption is proportional to the square root of the molecular weight for small fractions of the total surface covered. Thereafter, interaction of the adsorbed segments must be taken into account. For a given molecular weight, the number of anchor points, and therefore the heat of adsorption, are larger, the smaller the radius of the free coil or the more flexible the molecule. These workers also developed equations for multilayer adsorption along the lines of the Brunauer, Emmett, Teller theory (*68*). Application of these theoretical considerations to the retention of beater adhesives by cellulose fibers and other solid surfaces should lead to results of great benefit to papermaking.

Further studies are also needed on the composition and reactivity of fiber surfaces. The works of Thode and co-workers (*69–72*) with dye adsorption techniques, Dixson (*73*) on fiber surface conditions, and Allison (*74*) on fiber surface activity by alumina sorption should be continued and expanded. Gas adsorption techniques similar to those presently employed for exploring the surface properties of solid catalysts should be useful for investigating the surface properties of cellulosic materials.

The electrokinetic properties of both cellulose fibers and polymer dispersions and emulsions, as well as their interactions in the same system should receive further attention. Polymers and emulsified materials having electrical charges opposite to that on the cellulose fiber are generally retained very well at relatively low levels of addition. The difference in charge between the additive and fiber is soon neutralized at higher additions, however, and further quantities are retained weakly or not at all. Moreover, where cationic emulsifying agents have been used for stabilizing the polymer dispersion, it is almost invariably found that such surface-active material interferes with normal fiber-to-fiber bonding. This type of emulsion may weaken instead of reinforce the sheet. There is a great need for a low-priced cationic emulsifying agent which will decompose completely at drier section temperatures and volatilize or otherwise assume a form which will not interfere with fiber bonding.

Where deposition of larger amounts of polymer are desired or where extraordinary temperature resistance or plastic laminates are required, graft polymerization of various monomers within the fiber itself is arousing great interest. See in particular Bridgeford (*221, 222*).

Further elucidation of the molecular constitution of many of the polymers used as beater adhesives is also needed. This is particularly true in the field of hemicelluloses and natural gums. The works of Wethern (*77*), Thompson, Becher, and Wise (*75, 76*), and Thompson and Wise (*78*) in particular should be extended. The possible correlation of the mannan content of the hemicelluloses with their effectiveness as beater adhesives should receive further attention. Further information on this subject will lead not only to greater effectiveness of beater adhesives, but will further elucidate the role of hemicelluloses in normal fiber-to-fiber bonding and add to the basic knowledge needed for better pulp evaluation.

The future expanding use of beater adhesives will depend upon the extension of research and development in this field.

ADDITIVES WHICH AFFECT THE SURFACE PROPERTIES OF CELLULOSE FIBERS AND PAPERS

Many substances are combined with cellulose fibers to control surface properties of the fibers and the finished paper or paperboard. Broadly speaking, these materials are placed in two categories—internal sizing agents and surface-sizing agents. Internal sizing agents are used for making paper products resistant to penetration of water and various aqueous liquids. The paper industry is the largest consumer of rosin and waxes which are used for this purpose. Many other materials such as chemically modified rosins, asphalt emulsions, hydrocarbon resins, silicones, perfluorocarbons, polyethylenes, and other synthetics are also used. The natural resins of wood pulps may lead to self sizing and pitch troubles.

Surface-sizing agents are applied to the paper or board for the purpose of augmenting internal sizing and for improving such properties as porosity, abrasion

resistance, abrasiveness, erasability, finish, fuzz, smoothness, surface bonding strength, and printability. Among the materials employed for this purpose are chemically and physically modified starches, gums, glues, alginates, polyvinyl alcohol, methylcellulose, and carboxymethylcellulose.

Each of these major subjects, internal sizing pitch troubles, and surface sizing, will be discussed in terms of the fundamental concepts involved.

Internal Sizing of Paper and Paperboard

From a thermodynamic point of view, the penetration of water (or other Newtonian liquids) into paper or paperboard is a problem in achieving and maintaining a sufficiently low free surface energy upon the exposed fiber surfaces of the dried sheet. In a paper mill this is commonly done by precipitating rosin size with aluminum sulfate (papermakers' alum) onto the cellulose fibers and making the paper in the usual way. This is the process of internal rosin sizing. Other low energy materials may be used in place of rosin.

This process confronts the papermaker with various so-called sizing problems. Some pulps become sized with much greater difficulty than others. Some mills encounter poor sizing during the summer months or when high temperatures are employed in the stock system. Other mills encounter extreme variations in the degree of sizing from day to day or even from shift to shift. Still others may find that sizing is "fugitive," that is, the sizing is satisfactory immediately off the machine, but becomes unsatisfactory by the time the customer receives the product. And finally, there are the manufacturers of highly absorbent paper products who find that their products gradually become highly sized even though no sizing agent is ever added to the system.

Much research has been done to solve such problems. These investigations have been concerned chiefly with the mechanism of the rosin-alum sizing process in terms of the physical and chemical properties of the size precipitates and the cellulose fiber. Needless to say, numerous theories of sizing have been proposed. We shall not take the time here to review the many theories of rosin sizing and the associated polemics. The reader is referred to Casey (*86*).

The several theories of rosin sizing do not conflict with one another in all instances. Some theories consider sizing from different levels of the process than others. Certain theories take for granted the chemical composition of the sizing agent and a mechanism of retention is the principal consideration. In other theories, the opposite viewpoint is taken; that is, retention is assumed and chemical composition of the size precipitate is believed to be the controlling factor. It is, of course, axiomatic that best sizing will be obtained only if the precipitate has the correct chemical composition *and* is retained *and* is well distributed on the fiber surface. In spite of the apparent fulfillment of the basic requirements, sizing problems are encountered in modern practice.

Developments in the field of surface chemistry have established quite clearly many of the basic thermodynamic factors necessary for production of good sizing. These considerations do not yet permit easy solutions of all sizing problems, but recognition of these concepts often suggests more fruitful approaches to a sizing problem. Furthermore, the surface chemical concepts are vitally important when new sizing materials are designed for aqueous liquids, greases, oils, and fats.

In the following sections, the surface chemistry of sizing and several recent contributions to this field will be reviewed.

Penetration of Liquids into Porous Structures

Attractive Forces Between Liquids and Solids. Internal sizing of paper and board is concerned with the rate of penetration of liquids into irregularly shaped capillary structures. It has been clearly established that all spontaneous penetration phenomena depend ultimately upon the Van der Waals' forces of attraction between the molecules of the liquid and solid. The relationship between these forces may be expressed in terms of their corresponding attractive energies as the *work of adhesion*, W_{SL}, between the liquid and solid. This is stated in equation (7).

$$W_{SL} = \gamma_S + \gamma_L - \gamma_{SL} \qquad (7)$$

where γ_S, γ_L, and γ_{SL} are the specific free surface energies of the clean solid-vacuum, the liquid-gas, and the solid-liquid interfaces, respectively. These thermodynamic quantities are mathematically equivalent to the corresponding interfacial tensions where mutual solubility is negligible. Equilibrium is assumed.

The surface tension of a liquid is easily determined but the corresponding values for the solid-vacuum and solid-liquid interfaces cannot be reliably determined at the present time. However, the difference $\gamma_{SV} - \gamma_{SL}$ may be determined provided the liquid forms a measurable contact angle θ with the smooth solid surface. Here, γ_{SV} is the free surface energy per square centimeter of solid in equilibrium with the saturated liquid vapor. The contact angle is defined by a modified Young's equation (8).

$$\gamma_{SV} - \gamma_{SL} = \gamma_L \cos\theta \qquad (8)$$

Bangham and Razouk (*87*) showed that

$$\gamma_S - \gamma_{SV} = f_{SV} \qquad (9)$$

where f_{SV} is the decrease in free energy when the clean solid is immersed in the saturated vapor of the liquid. Combining (7), (8), and (9) gives

$$W_{SL} = f_{SV} + \gamma_L (1 + \cos\theta) \qquad (10)$$

This is the Young-Dupré equation. When the vapor pressure of the liquid is negligible, f_{SV} drops out and the work of adhesion is easily determined from the surface tension and the contact angle. When the vapor pressure may not be neglected, f_{SV} must be experimentally determined as shown by Bangham and Razouk (*87*).

The work necessary to separate unit area of a liquid from itself, that is, the *work of cohesion*, W_C, is

$$W_C = 2\gamma_L \qquad (11)$$

Equation (11) will now permit estimation of the relative attractions between the solid and liquid molecules. When the contact angle θ is finite, cosine θ will be less than unity and W_{SL} must be less than $2\gamma_L$ or W_C. If θ is zero, perfect wetting of the solid by the liquid occurs and W_{SL} is equal to *or* greater than W_C. In other words, when θ is finite, the attraction between the liquid

and solid is always less than the attraction between the molecules of the liquid. At 90° the solid-liquid attraction is only one half the cohesional attraction within the liquid itself. A 180° contact angle is obviously impossible. This would imply no attraction between the solid and liquid molecules. It has been established that all molecules and atoms attract others to an appreciable extent.

Penetration of a Liquid into a Capillary. The attractive forces mentioned above cause the surface of a liquid within a small capillary to become curved and because of the higher free energy in the surface region, a pressure difference develops across the meniscus (*88*). This pressure difference causes the liquid to spontaneously penetrate or resist penetration into the capillary depending upon the relative magnitudes of the attractive forces. This relationship is expressed by the fundamental equation of capillarity for a curved element of a liquid surface as follows:

$$P_1 - P_2 = \Delta P = \gamma_L \left(\frac{1}{r_1} + \frac{1}{r_2}\right) \qquad (12)$$

where P_1 and P_2 are the pressures on the concave and convex sides of the meniscus, respectively, ΔP is the pressure difference across the meniscus, and γ_L is the specific free surface energy of the liquid, and r_1 and r_2 are the principal radii of curvature of the curved liquid surface. If the capillary is a uniform cylinder of small, constant radius r and the attractive forces are such that a finite contact angle θ exists between the liquid surface and solid wall of the capillary, the surface of the liquid becomes an element of a sphere and radii r_1 and r_2 are equal. The pressure difference, ΔP, is then expressed by equation (13);

$$\Delta P = \frac{2\gamma_L \cos \theta}{r} \qquad (13)$$

It is often found in the experimental measurement of contact angles that the angle is larger when the liquid is advancing over the solid surface than when the liquid is receding from the solid surface. The difference between the so-called advancing and receding contact angles is spoken of as the hysteresis of the contact angle. We shall consider some of the factors responsible for this behavior later.

Now let us examine some of the implications of equation (13). When the contact angle θ is acute, the pressure difference across the meniscus is positive and the liquid spontaneously penetrates into the capillary because of this pressure difference. As the angle becomes larger and the cosine therefore smaller, the pressure difference becomes smaller. When the contact angle is obtuse, cosine θ is negative and the pressure difference resists penetration of the liquid into the capillary. Under this condition it is necessary to impose a hydrostatic head on the system in order for liquid penetration to occur. If it is assumed that capillaries exist in a sheet of paper, then equation (13) implies that best sizing should occur when the angle θ is as large as possible (preferably greater than 90°) and the radius of the capillary, r, is as small as possible. Generally speaking, the contact angle between the liquid and solid cellulose fiber is increased by internal sizing of the paper and the radius of the capillaries is made as small as possible by refining or by surface sizing the paper or board. Because of the hysteresis of the contact angle, it is to be expected that the pressure developed as the liquid enters the sheet

$$P_i = \frac{2\gamma_L \cos \theta_A}{r} \qquad (14)$$

will always be *less* than the pressure necessary to force the liquid out of the sheet, P_0,

$$P_0 = \frac{2\gamma_L \cos \theta_r}{r} \qquad (15)$$

That is to say, because $\theta_A > \theta_R$, $P_0 > P_i$.

Rate of Penetration into a Capillary. Although equation (13) describes the necessary conditions for spontaneous movement of the liquid into the capillary or resistance to the entrance of the liquid into the capillary, it says nothing about the rate of penetration of the liquid into a capillary when the contact angle is acute. Where the driving pressure is limited to the capillary pressure, equation (13) may be combined with Poiseuille's equation for volume rate of flow through a capillary (16).

$$V = \frac{\Delta P r^4 T \pi}{8\eta L} \qquad (16)$$

This yields equation (17) expressing the depth of penetration of liquid in a given time,

$$L^2 = \frac{\gamma_L r T \cos \theta}{2\eta} \qquad (17)$$

where L is the distance penetrated in time, T, and η is the coefficient of viscosity of the liquid. Differentiation of equation (17) with respect to time gives the corresponding rate of penetration, equation (18):

$$\frac{dL}{dT} = \frac{\lambda_L r \cos \theta}{4\eta L} \qquad (18)$$

This is often referred to as the Washburn equation (*89*). It is valid only when the contact angle θ is acute, when laminar flow exists and, when air resistance and gravitational and inertial effects may be excluded or neglected.

These equations apply strictly only to a single, uniform, cylindrical capillary. The porous structure of paper and board is much more complex. Here, the pores are not uniform cylinders and the variations in their size and the numerous bifurcations, constrictions, and interconnections further complicate penetration in such systems. On the other hand, Peek and McLean (*90*) have indicated that the rate of penetration into a complicated network of capillaries requires no more complex dependence on γ, L, and η, than does a simple capillary. However, there is little doubt that the theory of penetration into capillaries of complex shape is difficult. Aggregates of fibers such as paper and board may be treated formally as equivalent to capillary structures and equations (14) and (15) may be used to calculate the contact angle from the observed pressure P_i produced by the penetrating liquid or P_0, the pressure required to expel the liquid. It is clear that the radius, r, in the fundamental equation is not a simple average of the measured pores in a sheet of paper and board. However, it sometimes becomes desirable to determine the radius, r, of the "equivalent capillary" and this is done by measuring the viscous resistance to flow of liquids or gases through the porous structure. The reader is referred to articles by Bartell (*91*), Carman (*92*), Carson (*93*), and Baxter and Cassie (*94*).

These methods may be useful but they conceal our ignorance of the manner in which the liquid actually finds its way into the nooks and crannies of the porous solid where the pores frequently and abruptly change size and shape. Adam (*95*) has given some consideration to this problem. His simple geometrical considerations show that the penetration pressure, P_i, will decrease and may even become negative, when the meniscus has to find its way past a constriction in a pore.

The exchange of liquids between paper pores has been studied by Tollenaar (*96*). He concluded that the capillary rise of liquid in paper cannot be explained quantitatively by assuming uniform capillaries, but suggests the use of a distribution function for the capillary radii which amounts to a correction term for the capillary pressure of the volume of liquid at any level of penetration. Calderwood and Mardles (*97*) have studied the rate of flow of liquids into capillaries under the action of surface forces and found the rates of penetration were less than those predicted, especially in dry tubes, even through the contact angle was zero or quite small. The movement under small forces was found to be very jerky and often rhythmic in recession, the rate being considerably less than the calculated value. Hysteresis of the contact angle was found to be inadequate in explaining the dynamic phenomena observed in their study. The initial rate of penetration into the capillary, which from equation (18) could be very large at the instant the liquid begins to enter the capillary, was found to be considerably less than the calculated value. This is explained by a reversal of flow of the liquid at the meniscus and turbulence which is developed by the energy involved in setting into motion the liquid outside the capillary. It is clear that much further work needs to be done on the influence of complex capillary structures on the rate of penetration. A thorough discussion of penetration phenomena in more complex systems has been presented by the staff of The Institute of Paper Chemistry (*98*).

Little appears to have been done in the field of high-speed wetting and penetration. The reader will find the Knight rapid wettability tester of interest (*99*).

Factors Which Affect the Contact Angle; Contact Angles on Plane and Rough Surfaces. Although the structure of paper may be complicated, it is clear that the contact angle determines whether or not spontaneous penetration of the structure by the liquid occurs in a finite time. Let us examine more closely the factors which determine the contact angle. It was stated earlier that the magnitude of the contact angle between the liquid and a plane solid surface depends upon the relative magnitudes of the Van der Waals' forces of attraction between the liquid molecules themselves and between the molecules of liquid and solid. These forces determine the wettability of the solid surface. Solving equation (8) for the cosine of the advancing contact angle θ_A gives (19).

$$\cos \theta_A = \frac{\gamma_{SV} - \gamma_{SL}}{\gamma_L} \qquad (19)$$

This shows that the cosine of the contact angle is the ratio of the free energy change in forming a *unit area* of the solid-liquid interface and the energy required to form a *unit area* of the liquid-air interface. It must be emphasized that (19) is a geometrical relation and that the unit areas are plane geometrical areas for each of the interfacial energies involved. Although the area of the liquid-air interface may be equal to its plane geometrical area, this is not true of the solid-liquid or solid-gas interfaces. Most solid surfaces are quite rough. The change in surface free energy of a rough surface will differ from that of a unit of plane geometric surface. This was shown first by Adam (*88*) and Wenzel (*100*) and more recently by others (*101*). If a solid surface is rough so that a unit plane geometrical area has an actual surface area σ times that of the plane smooth surface, the free energy change in forming the solid-liquid interface will then by $\sigma(\gamma_{SV} - \gamma)_{SL}$ and the *apparent advancing contact angle* for the rough surface is given by equation (20).

$$\cos \theta_{AA} = \frac{(\gamma_{SV} - \gamma_{TL})\sigma}{\gamma_L} = \sigma \cos \theta_A \qquad (20)$$

As pointed out by Cassie (*102*), any rough surface must have two advancing and receding contact angles. The apparent angles are evident on casual inspection of the intersection of the solid and liquid surfaces and the "real" angles are seen by close inspection on a magnified scale comparable to the scale of the roughness of the specimen. The measurement of contact angle is, therefore, somewhat arbitrary. When one approaches molecular dimensions, any surface would appear to be rough and heterogeneous in its structure. However, for practical purposes it is possible to separate surfaces into "smooth" and "rough" and so attach a meaning to the "real" and "apparent" contact angle. However, the smooth surface must be reproducible or the "real" contact angle will not be reproducible. The difficulty of reproducing "smooth" surfaces is one of the reasons that so many different values for contact angles of a given liquid and solid have been published. When the solid surface is rough, equation (20) indicates that θ_{AA} is greater than θ_A if θ_A is obtuse ($\gamma < \gamma_{SL}$), and θ_{AA} is less than θ_A if θ_A is acute ($\gamma_S > \gamma_{SL}$). In other words, roughness of the solid surface simply magnifies the wetting *or* nonwetting property of the surface depending upon the magnitude of the real contact angle, θ_A.

Heterogeneous Solid Surfaces. Cassie (*102*), and Cassie and Baxter (*103*, *94*) have given further consideration to the influence of roughness, and heterogeneity of the solid surface on the contact angle. These factors are particularly important to paper sizing because of the fibrous structure of the surface and because the sizing agent probably is not deposited uniformly on the fibrous surface. Thus, the specific free surface energy will differ from one area to another.

The effects of heterogeneity on the apparent advancing contact angle can be obtained by extending the considerations given to roughness. If a unit geometric area has an actual surface area σ_1, having a specific free surface energy γ_{S_1}, and an actual area σ_2, having a specific free surface energy γ_{S_2}, then as the liquid spreads over the solid surface the free energy change $(\partial F/\partial S)_{T,V}$ will be

$$-\left(\frac{\partial F}{\partial S}\right)_{T,V} = E = \sigma_1(\gamma_{S_1} - \gamma_{S_1L}) + \sigma_2(\gamma_{S_2} - \gamma_{S_2L}) \qquad (21)$$

where T and V refer to constant temperature and volume and the other symbols have their usual significance. The apparent advancing contact angle θ_{AA}, for the composite surface should be given then by

$$\cos \theta_{AA} = \frac{E}{\gamma_L} = \sigma_1 \cos \theta_1 + \sigma_2 \cos \theta_2 \qquad (22)$$

where θ_1, and θ_2 are the real contact angles for each type of surface. This equation is general and should apply to any number of types of surfaces provided the area does not involve so few molecules that thermodynamic considerations become invalid. Schulman and Zisman (*104*) have examined this situation for low energy solids and Cassie (*102*) and Shuttleworth and Bailey (*101*) have treated the more general case.

In paper, the most important heterogeneous surface is the porous surface although nonuniform distribution of sizing agent should not be neglected. For porous paper or board, σ_1 becomes the solid fiber surface area and σ_2 represents the area of air spaces per unit geometric area in equation (22). Then γ_{S_2} is zero, and γ_{S_2L} becomes γ_L and

$$\cos \theta_{AA} = \sigma_1 \cos \theta_1 - \sigma_2 \qquad (23)$$

Equation (23) shows that whereas the roughness factor σ_1 may *either* increase *or* decrease θ_{AA}, depending upon whether θ_1 is obtuse or acute, the porosity factor σ_2, always increases θ_{AA}.

The geometry for an idealized fiber system has been given by Cassie and Baxter (*103*), who demonstrated that equation (23) is valid within the limit of experimental error. It is clear from their work that apparent advancing contact angles up to 150° can be obtained with appropriately spaced fibers on which the real advancing contact angle is not over 90°. The superior water repellency of duck's feathers results from the almost ideal spacing of the barbules and not from a superlative sizing agent. Where the real advancing contact angle is greater than 90° a rough surface can behave as though it were porous because of air pockets trapped in the roughness of the surface.

Shuttleworth and Bailey (*101*) have given further thought to the process of spreading over a rough solid surface. They maintain that the final position of a liquid at rest (where gravity is neglected) is in stable *or* metastable equilibrium when the total surface energy of the system is a minimum. This requires first, that the liquid have a minimum surface area (hence minimum surface energy). This requirement is met when equation (24) is satisfied.

$$\frac{1}{r_1} + \frac{1}{r_2} = \text{constant} \qquad (24)$$

where r_1 and r_2 are the principal radii of curvature of the liquid surface. The second requirement is that Young's equation (8) must be satisfied. Thus, when a liquid is placed on a solid surface and covers an arbitrary area, the liquid-gas interface quickly assumes a shape which satisfies equation (24). Then in order to satisfy Young's equation, the liquid spreads or recedes until both (24) and (8) are satisfied. This produces a position of minimum of total free surface energy; however, it need not necessarily be the absolute minimum which yields θ_{AA} from Wenzel's equation (20). Positions of metastable equilibrium are possible. Shuttleworth and Bailey also consider the effects of two- and three-dimensional roughness and spreading parallel and perpendicular to the grooves in the two-dimensional case. They maintain that the boundary edge, where the liquid meets the rough solid, will be ragged in order for the liquid to intersect the solid surface at the real contact angle. The apparent advancing contact angle θ_{AA} then becomes the algebraic sum of the real contact angle θ_A and the angle of inclination of the asperities of the surface. Hysteresis of the contact angle occurs because the liquid comes to rest at a different minimum total surface energy after spreading and receding.

Bartell and Shepard (*105*) have studied further the effects of roughness of paraffin surfaces upon the hysteresis of the water-paraffin contact angles. They found that the advancing contact angle increased with an increase in the angle of inclination of the face of the surface asperities, but the receding angle was hardly affected. Hysteresis also increased with increased angle of inclination but was independent of the height of the asperities.

The Effect of Surface Roughness on the Rate of Water Absorption in Paper. From the considerations presented above, it would be expected that the roughness and porosity of paper should affect the degree of sizing of papers and board. A sized paper with a real advancing contact angle greater than 90° should absorb water more slowly, the rougher the surface and the more bulky the sheet. However, an unsized paper with θ_A less than 90° should absorb water at a greater rate when the surface is rougher and the sheet more bulky. Although the advancing contact angle on a smooth layer of rosin size is 100 to 105° (*106*, *107*), well-sized writing and drawing papers of the porous type may show a contact angle of 130°. Probably this difference results from the effects of surface roughness.

Arlov (*108*) has published measurements of the effect of roughness of paper on the water-paper surface contact angle. His results confirm the theoretical predictions. However, it is unfortunate that the roughness differences were produced in his papers by varying the degree of refining of the pulp and adding a constant amount of size. Quite probably the increased specific surface of the pulps reduced the proportion of sizing material on the surface and produced fiber surfaces which were more heterogeneous with regard to surface energy. It would be better to produce different surfaces by pressing the sheets with plates of different roughness.

Bäck and Lundin (*109*) have also considered the problem of measuring contact angles on paper surfaces. They point out, as also brought out by Cobb and Lowe (*110*) many years ago, that the contact angle should be used as a measure of liquid resistance only when the surface properties of the paper are of interest. Measurement of the decrease of contact angle with time is not a good measure of the water resistance of a paper. Such a measurement is very complicated and does not measure surface properties alone.

Effects of the Chemical Nature of the Underlying Solid. It is well established that each type of molecule has characteristic attractive forces for other molecules. Changes in the molecular species in the first layer of a solid should then markedly affect the contact angle even on a plane surface. Surface chemical studies have shown that the effective first molecular layer on a solid surface may be changed by a number of factors. Among these are the following:

1. The chemical composition of the molecule.
2. The structure of the molecule, degree of branching, ring

structures, degree and position of unsaturation, isomerism, molecular weight, etc.

3. The orientation of the molecule on the solid surface.
4. The degree of packing of the molecules on the solid surface.
5. The strength of anchorage of amphipathic (polar-nonpolar) molecules in an oriented position.
6. The nature of the underlying solid molecules.
7. Possible electrical charge effects.

Langmuir (*111*) studied the behavior of various plane solid surfaces in contact with water. He showed that drops of water placed on clean surfaces of glass, platinum, mica, calcite, sphalerite, and galena spread over the surface, wetting it completely, thus giving a zero contact angle. The clean surfaces are hydrophilic and, therefore, possess a high free-surface energy. However, after a monolayer of a fatty acid had been deposited on each surface it became hydrophobic and the contact angle depended greatly upon the character of the underlying solid. With mica the angle was 18°, for glass 45°, for platinum 65°, for calcite 70°, for sphalerite 82°, and for galena 86°. Because the chemical composition was the same in the first layer of molecules on all of these solids and because the Van der Waals' forces of attraction decrease with such a high power of the distance of separation one might expect that the contact angle between the surface layer of molecules and droplets of water would be the same in all cases. Langmuir showed that the differences observed in the contact angles resulted from the difference in the strength of anchorage of the amphipathic molecules to the solid surfaces. In other words, the fatty acid molecule has two ends which differ very much in their intrinsic free-surface energies. The hydrocarbon end of the molecule has a low free surface energy and tends to promote a high contact angle with water. The carboxyl group on the opposite end of the molecule has a high intrinsic free-surface energy and tends to promote wetting or a low contact angle with water.

Although probably the attraction between the carboxyl group and each of the solid surfaces is sufficiently great to orient the molecule in a position with the hydrocarbon radicals farthest away from the solid surface, a drop of water also possesses attraction for the carboxyl groups and competes with the solid surface for such groups. Thus, the contact angle between water and the monolayer deposited on the solid surface depends upon the strength of anchorage to the solid surface and the proportion of amphipathic molecules which can be overturned and brought into contact with the water surface. It was shown that mica anchors the carboxyl groups least strongly whereas galena anchors the carboxyl group most strongly. The effect of anchorage of rosin compounds in paper sizing has been studied recently by Guide (*112*).

Rideal and Tadayon (*113*, *114*) have shown that the contact angle between water and solid crystalline stearic acid decreases with time because of the mobility of stearic acid molecules in the solid state and the orientation of the carboxyl groups into the interface between the solid acid and water. Monolayers of C_{14}-labeled stearic acid deposited on a mica strip were found to transfer molecules to another strip when brought in contact with it. The rates of transfer and the partitions at equilibrium were determined for a variety of contacting surfaces. The rate of transfer was found to increase with increasing temperature. It was shown that the presence in a solid surface of small amounts of ions which could react to form a salt with the monolayer acid caused that surface to be favored with regard to the transfer and adsorption of the acid material. In another paper of this series (*114*) these workers showed that the transfer of stearic acid from one solid surface to another involved not only overturning and anchoring of the molecules but also surface diffusion. Surface diffusion over a solid surface has also been studied with radioautographic methods by Beischer (*115*).

Young (*116*) studied the migration of fatty acid molecules over the surfaces of various solids and showed that the apparent surface diffusion of such molecules occurs only by vapor-phase transport. That is, the molecules may become desorbed from the solid surface, evaporate, and then become readsorbed from the vapor state elsewhere on the solid surface where none of the molecules previously existed. He showed that if vapor-phase transport is suppressed no evidence can be detected for a true surface diffusion over macroscopic distances.

The various works cited seem to indicate that even though an amphipathic molecule capable of developing a high degree of sizing exists on a solid surface, a low contact angle will result if that molecule is not properly oriented and anchored. As indicated previously in equations (13) and (18), as long as the apparent contact angle is less than 90°, wetting and penetration of the paper structure will occur. Where contact angles greater than 90° exist for a period of time, it is believed that the amphipathic molecules present on the paper surface must be oriented and strongly anchored to the cellulose surface.

Bartell and Ray (*117*, *118*) have studied the contact angle relationships between cellulose derivatives and water and various organic liquids. They found a regular and systematic increase in hydrophobicity of the fatty acid esters with increase in length of the hydrocarbon chain. With acetate derivatives, hydrophobicity increased with increase in acetyl content and with substituent groups hydrophobicity increased in the order: hydroxyl, formyl, acetyl, hydrogen phthalate, ethoxy, nitro, propionyl, and benzoyl. The degree of polymerization had little influence on wettability of the surface. The effect of chemical composition of rosin and aluminum rosinates on the contact angle has been studied by Back and Steenberg (*119*) and by Ekwall and Bruun (*106*, *107*). The latter workers also studied the conditions of rosin sizing by basic surface chemical techniques—a much needed approach to this very complicated system. These studies demonstrated that the final reaction product between rosin acid and aluminum ions is dibasic aluminum monorosinate. This compound also gave the maximum contact angle with water.

Zisman and co-workers have studied the effects of chemical composition of low energy surfaces (*120*, *121*, *122*, *123*, *104*, *18*), and high energy surfaces (*124*) on wetting by various liquids. Generally speaking, low-energy surfaces are less completely wetted by liquids. Indeed, it has been possible to develop a sizing agent of sufficiently low surface energy that resistance to penetration by oils and greases can be imparted to paper even though the sheet is porous (*125*). Zisman's

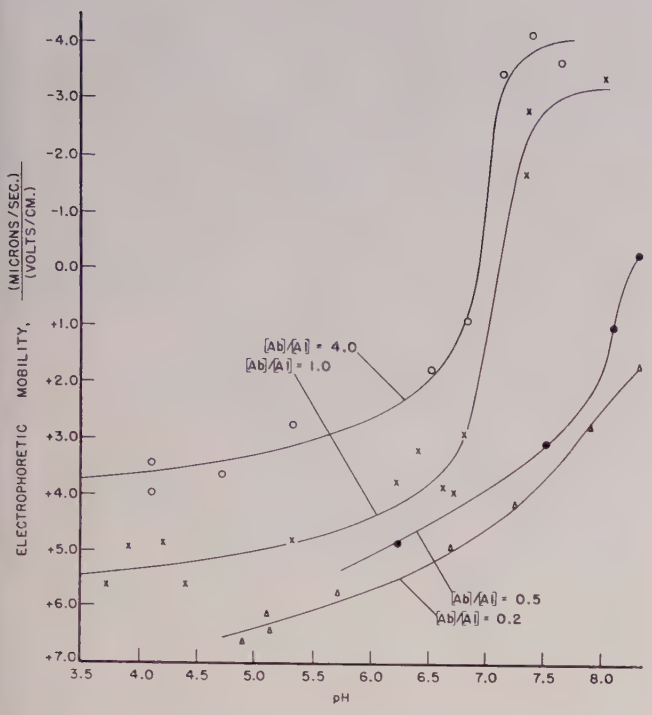

Fig. 13a. The effect of pH and initial abietate-to-aluminum mole ratio on the electrophoretic mobility of aluminate-abietate precipitates [From Guide (136)] [Abietate] = 0.001%

work shows that some high-energy surfaces adsorb certain liquids so strongly that an oriented monolayer is produced which no longer permits the remaining liquid to wet the solid surface. Such liquids are said to be autophobic.

Contact angles of liquids on starch, amylose, amylopectin, cellulose, and polyvinyl alcohol and the ethers of amylose and amylopectin have been studied recently (*126*, *127*).

Summary of Important Factors in Rosin Sizing of Paper

In summary, good rosin sizing depends upon the following:

1. Preparation of a size precipitate which has a potentially low free-surface energy.
2. Retention of the size precipitate upon the fiber surfaces.
3. Conversion of the wet sizing compounds on the solid surface to a stable low free-surface energy which remains fixed even though aqueous fluids are brought into contact with it.

What then do we know of the composition of the size precipitate and how to achieve the optimum composition for best sizing? What factors determine retention of the size precipitate? Finally, how can anchorage of the low free-surface energy size precipitate be obtained?

Composition of the Size Precipitate. Several workers have studied the composition of size precipitates in the alum-rosin or alum-abietic acid systems. (Abietic acid is the principal rosin acid.) Robinson (*128*) and Jayme and Seidel (*129*) believed that an aluminum triabietate existed in the size precipitate, but were not able to isolate it. Back and Steenberg (*130*) disputed this belief and concluded from their work that a precipitate which appeared to have the composition of aluminum triabietate was actually an equimolar mixture of aluminum diabietate and abietic acid. On the basis of her own work, Price (*131*, *132*) agreed with Back and Steenberg's interpretation. Ekwall and Bruun (*133*, *134*) studied the reaction product between rosin acids and aluminum sulfate under various conditions using the surface-balance technique. They concluded that the sizing material is dibasic aluminum monorosinate. They also showed that this compound gave contact angles which were 15 to 17° higher than those of the rosin acid. More recently Guide (*135*, *136*) studied the reaction products of sodium aluminate and sodium abietate under acidic and alkaline conditions and found that the size precipitates were not stoichiometric compounds but coprecipitates of several compounds. Free abietic acid was found in all precipitates. The compositions of the size precipitate were independent of the pH of precipitation, but dependent upon the initial abietate-to-aluminum ratio prior to acidification. Perchloric acid was used in his work to avoid the coordination complications which exist in other acid systems (see Figs. 18 and 19).

Retention of the Size Precipitate. Several workers have studied the relationship between sizing and the electrokinetic potentials of cellulose fibers and size precipitates. Collins, Davis, and Rowland (*137*) working with alum-rosin size precipitates found that both the pH of the system and the composition of the precipitate affected the potentials. Thode and co-workers (*138*) confirmed these effects and in further work (*139*) studied the electrokinetic potentials of sized and unsized cellulose fibers. They concluded that cellulose fibers dispersed in water have a highly negative potential, the sign of which is difficult to reverse. Thode's work (*139*) was confirmed by Ninck Blok (*140*). A comparison of electrophoretic mobilities of the size precipitates with their ability to size cellulose fibers was also made by Thode and co-workers (*138*). It was found that the most rapid increase in sizing ef-

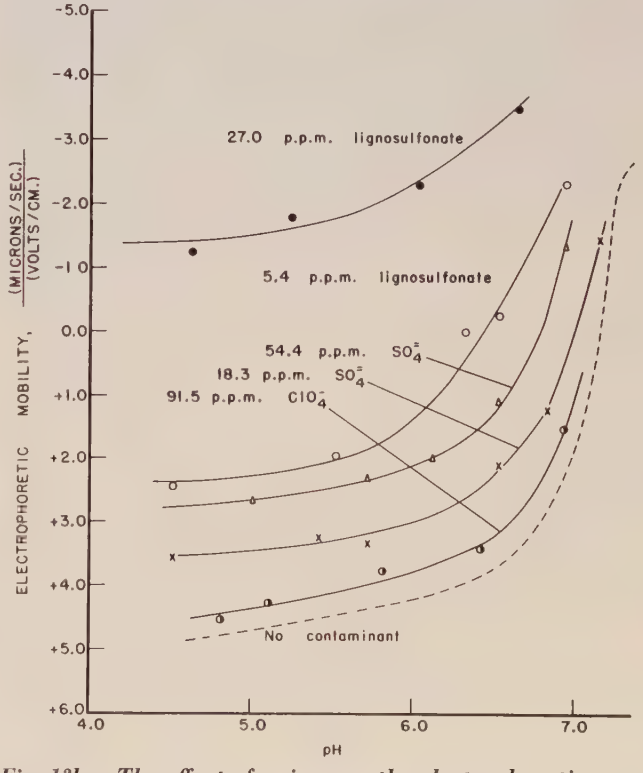

Fig. 13b. The effect of anions on the electrophoretic mobility of the aluminate-abietate precipitates [From Guide (136)]; [Abietate] = 0.001%; [Abietate] [Aluminum] = 1.0

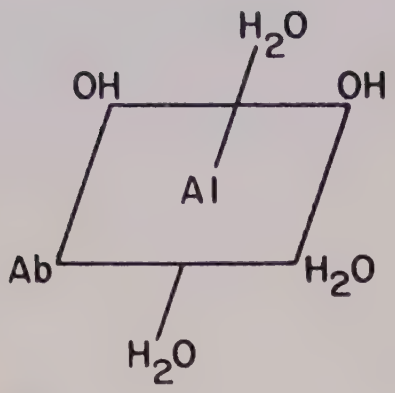

Fig. 14. Probable structure of aluminum monoabietate

ficiency was accompanied by the most rapid increase in electrophoretic mobility. They postulated that the size precipitates are attracted to the fibers because, under the conditions of rosin sizing, the precipitate has a positive electrokinetic potential whereas that on the fiber is negative. This difference in potential causes a mutual coalescence of the sizing material and the fiber. Guide (*136*) confirmed these effects and showed that the following factors assure a high positive potential on the precipitate: (1) a low initial abietate-to-aluminum mole ratio (0.5 or less), (2) a low pH of sizing (6.0 or less), and (3) a low concentration of easily sorbed anions in the sizing suspension. See Fig. 13a and 13b taken from Guide(*136*).

Conversion of the Size Precipitate to a Stable Low-Energy Surface. Papermakers have often wondered about the necessity for alum or a similar trivalent ion in the papermaking process. Simple acidification of the rosin size in the absence of alum will cause precipitation but very little or no sizing is produced in paper under these conditions. The works of Back and Steenberg (*130*), Ekwall and Bruun (*133*), and Guide (*135*) show that considerably higher contact angles (90 to 105°) occur between water and aluminum rosinate than between water and rosin acid (60 to 70°). The probable reason for the lower contact angle for the rosin acid-water system lies in the amphipathic (polar-nonpolar) nature of the rosin acid. During drying of a rosin acid precipitate the polar carboxyl groups quite probably orient inward from the surface to establish the lowest possible surface free energy. Thermodynamically, this situation would be favored. However, it appears that the molecules in such a surface are not necessarily fixed in position. The situation is dynamic

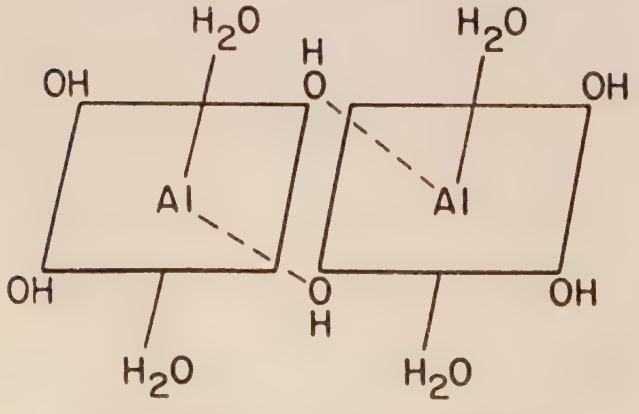

Fig. 15. Probable structure of olated dimer

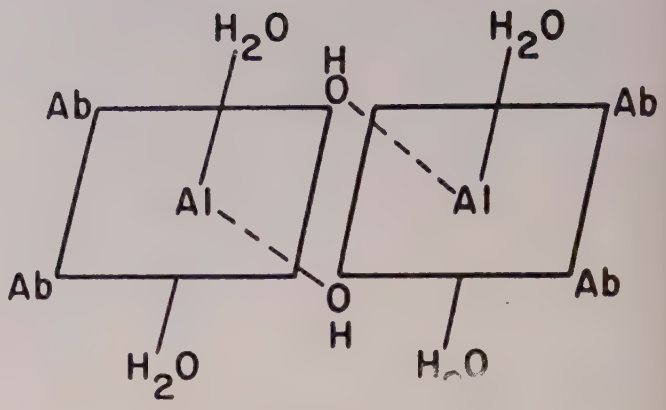

Fig. 16. Probable structure of olated aluminum diabietate

and some of the molecules will, on occasion, invert so that their higher energy carboxyl group then exists in the surface. When a strongly polar aqueous liquid is placed on such a surface, overturning of the molecules is favored by the adhesion of the carboxyl group for the water. Under such a condition, even though the initial contact angle is high, that is 90° or higher, it soon falls appreciably below this value as the amphipathic molecules overturn and increase the adhesion to water. It appears, therefore, that the presence of aluminum in the size precipitate somehow prevents or delays overturning of the polar ends of molecules in the size precipitate by anchoring them within the structure.

Cobb and Lowe (*141*), extended the suggestions of Thomas (*142*) and proposed that aluminum ions are capable of coordinating with various anions in solution and with hydroxyl and other groups on the cellulosic surface (see Fig. 14). This type of bonding between hydrated aluminum is called "olation." It is illustrated in Fig. 15. Guide (*136*) extended the concept of olation to size precipitates by assuming that the aluminum abietates are molecules of partially substituted aluminum hydroxide. The aluminum monoabietates may olate as shown in Fig. 17. The monoabietate dimer, in turn, may olate with similar neighboring molecules. However, aluminum diabietates can only form dimers or serve as end blocking groups in this polymerization as shown in Fig. 16.

Upon drying, the olated groups of molecules will lose their coordinately bound water. If the size precipitate is rich in aluminum hydroxide, many opportunities exist for the formation of ol bonds, and many molecules of aluminum abietate copolymerize.

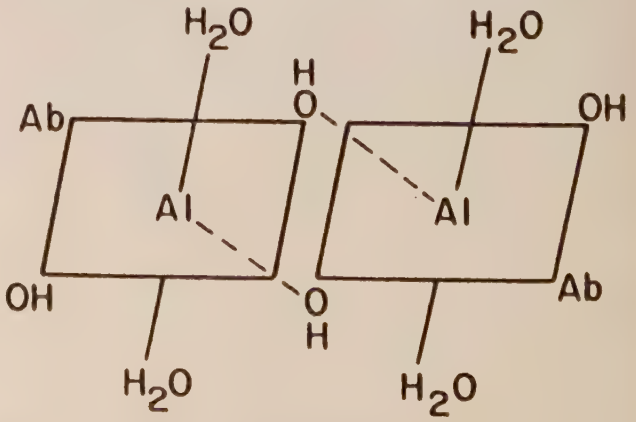

Fig. 17. Probable structure of olated aluminum monoabietate

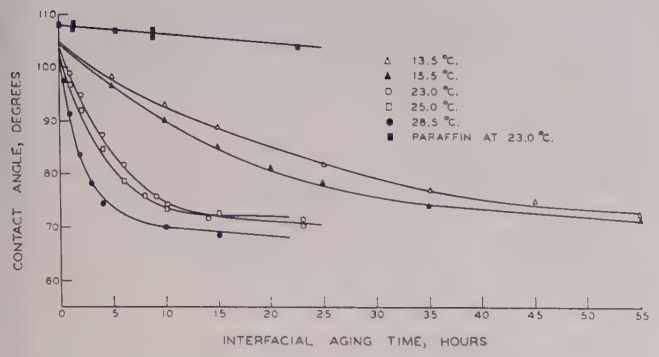

Fig. 18. The effect of aging on the wettability of stearic acid and paraffin [From Yiannos (144)]

But, if the size precipitate contains little aluminum hydroxide and mostly abietic acid and aluminum diabietate, little olation occurs, and the final precipitate on the fibers would consist largely of monomers and dimers. Presumably, the amphipathic molecules can overturn when the surface is brought into contact with water. Cobb and Lowe (*141*) concluded that the well-known detrimental effects of sulfate, tartrate, citrate, and oxalate ions on sizing are caused by their displacement of abietate ions from aluminum abietates. The former ions have greater coordinating power.

Rate Studies on Overturning of Amphipathic Molecules. There has been a great deal of speculation and interpretation of interfacial behavior in terms of overturning molecules in surface layers. Because of its importance to internal sizing of paper we recently began a series of studies which should lead ultimately to a much better understanding of this phenomenon. Some of the earlier literature, namely, the articles by Langmuir (*111*), Young (*116*), and Rideal and Tadayon (*113, 114*) have been summarized in the first part of this section.

The problem of molecular reorientation was tackled theoretically and experimentally in our laboratories by Yiannos (*144*). His study was concerned with reorientation of long-chain fatty acids but the work is presently being extended to rosin compounds. Employing the Maxwell-Boltzman statistical distribution law and interfacial tensions, Yiannos showed that 50% of the molecules at the top molecular layer of a long-chain fatty acid should reorient themselves so that the polar carboxyl groups face the water when this liquid is placed in contact. Experimentally, he studied the wettability of radioactive and nonradioactive monolayers and multilayers of fatty acids on solids. Mixed monolayers of stearic acid and stearyl alcohol on copper and silver allowed preparation of surfaces with variable ratios of mobile and stationary molecules. The stearic acid molecules were able to react chemically with the copper surface and remain fixed in position. Contact with water could not overturn these molecules. The reaction of the acid required much longer on a silver surface and this system was used to show the difference in interfacial behavior of the acid layers which were not anchored by chemical reaction. The experiments demonstrated that the reduction in contact angle upon interfacial aging in the presence of water is related to the mobile fraction of the monolayer and is due to molecular reorientation at the interface and not to moisture sorption and spreading of the solid on the water droplet used for contact angle measurements. The contact angle on paraffin surfaces remained high (105°) and practically unchanged over a long period of time. Wettability studies of multilayers of stearic, myristic, and lauric acids (18, 14, and 12 carbon atom chains, respectively), showed the same contact angle at equilibrium but the rates of attaining these equilibrium values were quite different. The shorter chain acid attained equilibrium much more quickly than longer chain acids (see Fig. 18).

Wettability studies of stearic acid multilayers at different temperatures permitted determination of the energy and entropy of activation for the reaction of wetting. The results show that the activation energy is approximately equal to the cohesive energy of the acid molecules.

The work on reorientation and molecular transfer now permits a more careful examination of the factors which determine the mobility of surface molecules in size precipitates. It also corroborates the hypothesis of self-sizing of wood pulp products set forth by Swanson and Cordingly (*143*). It is recalled that this hypothesis proposes that the rosin, fatty acids, and certain low energy neutral materials present in the unsized paper or board become redistributed throughout the surfaces of the fibrous structure by a process involving evaporation and adsorption. The result is a gradual decrease in free surface energy of the cellulose so that loss of absorbency and self sizing finally develop. Deposition and anchorage of the low-energy components undoubtedly involve many principles common to the rosin size-cellulose system. Anchorage of fatty acids may occur through reaction with calcium, magnesium, aluminum, and other multivalent ions in the pulp, by the presence of more bulky molecules which condense certain monolayer films, and, in the case of unsaturated fatty acids through polymerization. Much more interesting work remains to be done in this field.

Additives for Pitch Problems in Papermaking

Most paper and board manufacturers have encountered pitch trouble in one of its various forms from time to time. In some instances the trouble may appear in the form of pitch balls which vary in average size up to $^1/_4$ in. diam. The smaller pitch balls may pass through the screens causing dark spots in paper and board, picking, sheet breaks, resinous deposits in the fourdrinier wire and dandy roll, and poor sheet formation. In other instances the pitch is invisible within the pulp but it apparently assumes a very tacky condition and deposits on various parts of the machine which the pulp or sheet contacts. Felts are filled up rapidly and pitch may deposit upon the walls of pulpers, beaters, pumps, and various other kinds of tanks. It also collects upon drier rolls and breaker and calender stacks. These deposits not only lower the quality of the printing surface but often actually tear the sheet and lower production. In still other instances the presence of pitch causes loss of absorbency and development of sizing in products where this is undesired. The presence of pitch may also be undesirable in pulps which are intended for dissolving purposes such as cellophane and rayon manufacture. In this instance, the presence of very small quantities of pitch will cause discoloration, will greatly slow the rate of filtration of the viscose solution, and may produce cratering of the spinnerets during the spinning operation.

Review of the Literature on Pitch

Numerous references to pitch troubles have been made in the literature. Good reviews have been given by Phillips (*145*), and by Kress and Moss (*146*). Chemical companies supply numerous dispersants, protective colloids, pigments, and so forth, as pitch-control agents. However, it is well known that pitch troubles are very unpredictable and often, when the trouble is most acute, none of the pitch-control agents are effective. On the other hand, certain materials sometimes decrease the severity of the trouble. There seems to be no logical explanation in the published literature for the variable behavior of pitch trouble.

Some investigators believe that the pitch which is free of the fibers in a papermaking system, passes through a tacky stage as polymerization and oxidation occur. It is suggested that while in the tacky condition very small pitch particles may agglomerate into balls and deposit on various parts of the paper machine. From a colloidal point of view, it appears that only the free particles of resin could cause trouble. If this is so, coagulation and agglomeration of such particles should be governed by the theory of Verwey and Overbeek (*147*). Such colloidal materials are stabilized either by electrical charge or adsorbed protective colloids or both. This is the basis of use of many of the chemical additives but there is little fundamental information on their effects available in the literature.

Also, there is a difference of opinion whether or not pitch particles should be protected and prevented from agglomeration and coagulation or purposely precipitated upon the fibers and sold for the same price as paper. Many pulps contain approximately 1.0% pitch and even a 100-ton-per-day mill would, under this condition, sell a substantial quantity of pitch. It is evident, however, that only a part of this pitch can be termed "troublesome." If 20 tons of pulp containing 1% of pitch pass over a paper machine, approximately 400 lb. of pitch would be present in this pulp, but only about 0.04 lb. or 200 g., roughly 0.1% based on the pitch or 0.001% based on the pulp, will precipitate out upon various parts of the machine. This amount is sufficient, of course, to cause many breaks and much machine trouble.

It appears to be clear that pitch trouble stems from the resins contained in the pulp. However, occasionally rosin size may cause a similar trouble, particularly in the summer months when warm, hard water and/or excess rosin and alum are used. Although it has never been firmly established, it seems probable that *high free rosin sizes* may sometimes be worse than fully saponified sizes.

Potter (*148*) attributes pitch trouble to the petroleum ether extractables present in the pulp. Other investigators, however (*145*), have been unable to confirm this. The total amount of pitchy material in a pulp or wood may be determined by extraction with ether and alcohol or alcohol-benzene mixture. However, it is apparently impossible to tell by chemical analysis or solvent extraction of the pulp whether pitch trouble will occur if that pulp is utilized on the machine. It is possible to stain pitch particles in a pulp by using a solution of Sudan III dissolved in 3 parts of alcohol and 1 part of water.

When resinous materials once become attached to machine surfaces the only way of removing them is by scrubbing with kerosene, gasoline, or some special detergent.

The Effect of Various Factors on Severity of Pitch Trouble

Wood Species. Pinewoods which generally have about 3 to 5% of pitch but which may go as high as 20% in certain cases, give more pitch trouble than sprucewood which has approximately 2 to 4% of resin. Hardwoods generally contain little resin acid but they contain rather large quantities of fatty acids and unsaponifiable material and their use may lead to severe pitch troubles. Birchwood, which is generally higher in extractives than some of the other hardwoods, gives more difficulty than aspenwood. Back (*149*) has pointed out that screening of chips may remove from 3 to 8% of the total resin with the sawdust. This resin consists of small particles exuded by pressure of epithelial cells which surround the resin canals. Such droplets of exuded resin harden rapidly by evaporation, polymerization, etc., and are rubbed off the chip quite easily. Back also suggests that the resin in the ray cells consists mainly of unsaponifiable matter; the canal resin appears to be high in unsaturated components.

Effect of Seasoning the Wood. It has been found that pitch trouble often decreases or even disappears if the wood is aged or seasoned (*145*), especially if the seasoning is done in chip form (*150*). Although no quantitative data are available, it is claimed that seasoning oxidizes and polymerizes the pitch which may contain appreciable quantities of unsaturated compounds. Such action is said to decrease the tackiness and reduce the possibility of coalescence between the particles. Kress and Nethercut (*151*) have shown, however, that tackiness of pitch is actually greater after seasoning wood. Back (*149, 152*) has shown that considerable volatilization of cymene and other similar materials, occurs during dry seasoning but when wood is stored under water the yield of crude tall oil is about 30% higher. He further states that partial oxidation and simultaneous polymerization of resins as well as the drying process all affect the viscosity of the resin which is very important to the deposition of pitch on various parts of the machine. On the other hand, some manufacturers of groundwood from southern pines and hardwoods have found that green wood often gives considerably less pitch trouble than the seasoned wood in this climate (*153*).

The Effect of Type of Cook. Perhaps even more important than the type of wood is the type of cook which the wood is given. Unbleached sulfite pulp appears to be among the worst offenders in this respect. Soda and sulfate pulps rarely cause pitch trouble. Apparently, a large part of the resin is removed by saponification and subsequent washings in the alkaline processes. Although no fundamental information is available as yet, it is clearly suggested that the principles of solubilization by colloidal micelles may play an important role in these operations.

The Effect of Washing the Pulp and Type of Water Used for Washing. Good washing of the pulp will often largely eliminate the troublesome pitch from the system. The washing operation should be done with *hot, soft water, not cold water.* Improvement in the

washing operation will often reduce the pitch content of a pulp by more than 50%. Hard water apparently increases pitch trouble whereas soft water decreases it (*148*). The importance of proper washing conditions and the role of surfactants has been shown by the work of Back (*154*), Rapson and Wayman (*155*), Samuelson (*156*), and Rapson (*157*).

It has been shown by several investigators that the alkali metal salts of the rosin and fatty acids have pronounced surface-active properties. Ekwall (*158*) and Back (*154*) have shown that the salts of abietic acid undergo micelle formation at concentrations above 0.014 to 0.016 *M*. Similarly, Corrin and co-workers (*159*) and Kolthoff and Stricks (*160*) have shown that the salts of dehydroabietic (*159*, *160*), oleic (*159*, *160*), linoleic (*159*), and lauric (*159*) acids undergo pronounced micelle formation. Harva (*17*) has made an extensive study of properties of tall oil rosin soap and its mixtures with fatty acid soaps in aqueous solution. It has also been shown that the fatty and resin acids present in most pitch samples obtained from softwoods, are capable of solubilizing the free acids, higher alcohols, sterols, and other materials present in the unsaponifiable fraction of the extractives of woods. The entire subject of solubilization by surface-active materials has been reviewed by McBain and Hutchinson (*162*). The importance of solubilization of resinous material in pulp washing has been shown by Back (*154*).

One of the interesting properties of colloidal micelles is their dissociation or breaking up when the concentration in the water is lowered by dilution below the critical micelle concentration. Dissociation may also occur if the pH is changed from alkaline to acidic or if multivalent ions which form insoluble salts with the acid ions are added. When micelle dissociation occurs, the solubilized material may precipitate from solution. Undoubtedly, pitch trouble in certain cases may be related to precipitation of solubilized materials.

The Effect of Bleaching. It is generally found that multistage bleaching of pulps is usually beneficial to the pitch difficulties. Undoubtedly, the several washing steps, the alkali treatment, etc., are responsible for the removal of pitch from the pulp which in turn decreases the amount of trouble. It is, of course, quite important to remove any residual calcium ion from pulps which are bleached with calcium hypochlorite. Gustafsson and co-workers (*163*) showed that low pH, the presence of alum, high temperature, and complex phosphates decrease the tendency of pitch to adhere to metal surfaces, whereas calcium ion and hard water, particularly above pH 6 increase the deposition and adherence of pitch to metal surfaces.

The Effect of Beating and Refining. The general rule with regard to this subject is to do as little as possible beating and refining of pulps which tend to give pitch trouble. It is believed that beating and refining damages the ray cells and loosens and frees the pitch from the fibrous surfaces. Where it is necessary to refine pitch pulps it is best to separate those pulps which tend to have the most pitch and refine them separately. Such pulps should be refined in the presence of a pitch-control agent, several of which will be described later.

The Effect of Foam and Dissolved Gases. Some workers (*164*, *165*, *166*), have attributed pitch difficulties to the dissolved gases which are present in water, particularly when these gases exist in the form of bicarbonate. It is claimed that during acidification of the water, such gases are liberated on the fiber surface and pry the pitch loose. The bubbles may collect the pitch particles and assist in agglomeration to larger pitch balls. Gavelin (*166*) says a water containing 100 p.p.m. of bicarbonate ion will liberate about 40 gal. of carbon dioxide at 760 mm. and 100°F. per 1000 gal. of water. When 800 gal. of fresh water are added to the system each minute, 32 gal. of carbon dioxide will leave the system, plus 25 gal. of dissolved gases (air when the temperature increases to 100°F.). There is little doubt that the presence of foam in a mill system will tend to increase the severity of pitch troubles. Pump packings should be examined and tightened and any incorporation of air into the system at backfalls and where the stock is churned should be eliminated from the system. Gustafsson and co-workers (*163*) were unable to confirm the suggested role of bicarbonate ion by their method of detecting troublesome pitch. An analysis of various forms of pitch is given in Table II.

Table II. Analysis of Various Forms of Pitch

	Extracted				
	Pine groundwood		*Mixed sulfite*[a]	*Breaker stack*	*Wire roll*
Rosin acids, %	8.3[b]	10.5	9.7	12.5	1.5
Fatty acids, %	47.3	17.2	33.9	11.8	12.0
Unsaponifiables, %	7.5	22.5	31.5	3.4	5.6
Ash, %	7.9	...	...	17.2	14.0
CaO	0.05	...	...	5.4	4.6

[a] 75% spruce; 25% aspen and birch.
[b] From canister tests.

Methods of Pitch Control

Chemicals. Sodium hexametaphosphate has been suggested as a pitch-control agent (*167*). The action of this material has been variously explained as sequestration of the multivalent ions in the system which augment pitch trouble and also as the formation of a passivating layer of phosphate on the solid surfaces in the system (*168*). The latter action prevents adherence of the pitch particles to the solid surfaces. In some mills, polyphosphates apparently work quite well but in others no beneficial effect can be observed. Gustafsson (*163*) has shown that sodium chloride and bicarbonate ions have little or no effect upon the depositable pitch at pH 7.0 and 40°C. However, magnesium ions and calcium ions increase the deposition of pitch when present in the system at a pH of 7 and 40°C. Calcium ion is particularly effective in increasing the depositable pitch in the pH range of 6 to 10 but there apparently is no effect on the depositable pitch at pH ranges of 4 to 6. They found that presence of aluminum ion decreases the depositable pitch at pH 7 but at pH 5 there is apparently a maximum in the depositable pitch at an aluminum ion concentration of 15 mg. per l. and 40°C. This behavior should be compared with the work of Back (*152*) who has developed a pitch-control method involving the addition of sodium hydroxide and alum to the pulp. His treatment consists of the addition to the pulp as early as possible in the system of about 0.3 to 0.5% NaOH accompanied by stirring for about 5 min. Then 0.2 to 0.5% of excess alum (sufficient to bring the

pH to 5.5 to 6.0) is added to the system. Too much excess alum is undesirable in this treatment because it apparently increases the depositable pitch content of the pulp. Back believes that this treatment produces a negative charge on the cellulose fibers and a positive charge on the pitch particles which are then attracted to the fiber surfaces and held there; they are then carried out of the system with the paper. The treatment prevents build-up of tacky particles within the system so that pitch balls and other troublesome forms of the tacky pitch do not develop.

Stroele and Teves (*169*) have published an interesting comparison of the effects of various dispersing agents on the depositable pitch as determined by several techniques.

Sequestering agents based upon ethylenediaminetetraacetic acid have been suggested as a means of removing the harmful effects of water hardness which may exist in the form of calcium, magnesium, and iron compounds. These compounds are added continuously to the shower water at the grinders of groundwood mills encountering pitch troubles. In the case of sulfite mills, it is best to add the compounds to the suction side of the fan pump before the stock is pumped to the stock chests. Gustafsson has shown the beneficial effect upon depositable pitch by the use of such sequestering compounds in the presence of hard water.

Swanson and Cordingly (*170*) have considered the surface chemical aspects of the pitch problem. They showed that certain components of the pitchy material may form films upon the aqueous surface of the pulp suspension. Such films may collapse or form pitch balls depending upon the conditions of temperature, pH, ion concentration, etc., in the hypophase. An interpretation, based on their surface chemical considerations, is given of some of the apparent anomalies encountered with the use of chemicals as pitch-control agents.

Additives for Surface Sizing of Paper and Board

Surface sizing of paper and board differs considerably from internal sizing in purpose as well as principles and practice. In general, surface sizing consists of the application of an aqueous dispersion of one or more materials to the surface of paper or board for the purpose of controlling porosity, smoothness, fuzz, and strength properties of the product. More broadly, the process is used to correct or apply color, apply fluorescent brighteners, correct paper acidity, improve dimensional stability, provide wet rub and wet strength, fireproof, improve pliability or increase stiffness (*171*), control subsequent wax and oil penetration, and improve printability.

Tub Sizing. In some operations, more properly called tub sizing, the dry (5 to 12% H_2O) paper is passed through a 5 to 15% solids dispersion of modified starch, glue, or other suitable polymer which penetrates the paper structure quite deeply. This type of treatment is often given to high-grade rag or rag content papers such as bond, banknote, writing, and chart papers. Strength properties are increased substantially. For example, bursting strength may be increased 20 to 35%; tensile strength, 20 to 30%; folding endurance, 100 to 500%; and pick resistance and writing properties are improved substantially. Where wet strength is desired, as in blueprint papers, the glue may be treated with formaldehyde although it is more common to use wet-strength resins today. All of these strength improvements are obtained with little or no detriment to tearing strength. This is a difficult feat to accomplish by mechanical refining. Normally, over the usual range of papermaking conditions, tearing strength drops sharply whenever anything is done to improve fiber bonding. This effect also occurs when beater adhesives are used for improving strength unless mechanical refining is decreased.

The degree of sizing, as measured by many of the usual water-penetration tests, is often not changed appreciably by tub sizing. At first thought this may seem strange because of the lower porosity of tub-sized papers. The Washburn equation (*89*), however, predicts this result might occur. Recall that the rate of penetration [see equation (18)] is directly proportional to both the cosine of the contact angle and the radius of capillaries. Thus, although the lower porosity would decrease the rate of penetration of a sized paper, the hydrophilic starch or glue film covers some of the low-energy surfaces produced by internal rosin sizing and lowers the contact angle. The latter effect yields a greater cosine value and counterbalances the effect of smaller pore size. Often, the two competing effects leave the size value unchanged unless the sheet becomes very highly plugged. On the other hand, tub sizing always improves pen and ink sizing and feathering on the surface. Where extreme resistance to feathering is required, as in recording chart papers, a small amount of wax emulsion may be added to the tub-sizing solution. Waxes must be employed with caution; however, too much will cause uneven wetting of the paper surface by the ink.

Size Pressing. In other operations, part way through the drier section of the machine, the sheet is passed through a size press. This is a vertically or horizontally arranged two-roll nip that is flooded with the polymer dispersion. Here, the contact time is shorter and less penetration of the sheet occurs. The horizontal size press has gained in popularity recently. Whitworth (*172*) says this equipment can handle higher solids contents than the vertical size press and can be controlled more easily. Some mills put clays or other pigments in the sizing dispersion for improving brightness, color, and two-sidedness of papers, or for putting on a first coating in a double-coating process. This process is called size-press coating.

Calender Sizing. Many other mills, particularly those who manufacture heavier weight papers and paperboards apply suitable dispersions from the water boxes of the calender stack. This too, involves short contact time between paperboard and the solution which permits little penetration beyond the surface layer of fibers.

In all three processes numerous factors control penetration, pickup, and/or film-forming and strength qualities of the materials applied. Among these are roll pressures and roll softness, moisture content of paper or board, density, degree of internal sizing, temperatures of paper and sizing solution, hot and cold viscosities and solids content of sizing solution, and particle size and molecular weight of the sizing materials.

For information on sheet structure and mechanical factors, the reader is referred to Casey (*86*) and to Stephenson (*173*).

Major Materials Used for Surface Sizing—Glue. Chemically modified starches and glues are the principal adhesives used for surface sizing, but numerous other polymers, pigments, dyes, and emulsions are often used along with starches for achieving special effects.

Glue has long been used as a tub-sizing adhesive and where maximum strength improvements and surface properties are desired, it is still one of the best materials. Being an amphoteric colloidal electrolyte, its viscosity and penetration properties may be varied considerably by compounding with alum or mild alkalies. Glue is not commonly used as a calender sizing agent, however, because of its higher cost and tendency for sticking to roll surfaces.

Glue is classified on the basis of its jelly strength. A high jelly strength glue will generally provide higher strength properties to the paper and better continuity of film. The better glue products, in terms of strength, color, foaming tendencies, etc., were, until recently, obtained from hides but now high-grade, lower cost bone glues are available. Even these are used mostly in high-grade, expensive papers.

Modified Starches. The use of starches for all types of surface sizing has increased greatly during the last 25 years because starches have greater versatility and lower cost than many other materials. Both starch producers and paper companies have done considerable research on the development of new starch products which have a wide range of properties. Although unmodified cooked starch is sometimes used at low solids contents for calender sizing, most surface-sizing applications require that the starch be modified to reduce its viscosity. The reason for this is that solutions of natural starches are too viscous to be applied at the usual concentrations (5 to 15% solids) and if their concentration is reduced to a desirable or workable viscosity by dilution, so much water is necessary that sufficient starch to be effective is not present. It is necessary, therefore, to use modified starches which possess low viscosities at high concentrations. Similar starches are required as pigment-coating adhesives. Excellent summaries on measuring the useful properties of starches and recent developments in starches for coating are given by Elder and Schoch (*180*) and Schoch (*181*).

It is well established that unmodified starch has the highest adhesive strength per unit weight. However, because an insufficient number of units of the starch can be introduced to the paper it is necessary to degrade the product so that more units of lower strength starch may be introduced and the overall strength thereby improved. The converted products normally found on the market or prepared for use at the paper mill are prepared by one of the following processes: (1) acid hydrolysis, (2) dextrinization, (3) oxidation, (4) enzymatic hydrolysis, or (5) derivatization.

The proper choice of modified starch for a given converting operation depends upon a great many factors among which may be mentioned the cost, the adhesive strength, the degree of penetration desired, and color. Each of the five methods of modification affect the polymers of starch in a different way and the changes produced influence greatly the colloidal properties of the resultant modified starch. Before proceeding with a discussion of the effects of these converting operations on the modified product, let us review briefly the chemical and physical structure of starch.

Table III. Comparison of Properties of Amylose and Amylopectin

	Linear chain Amylose	*Branched chain Amylopectin*
Solubility in water	Originally soluble in warm water	Soluble after separation from amylose
Colloidal stability	Spontaneously precipitates at concn. above 0.5%	Very stable in 5% solutions
Gel properties	5% solution sets quickly to tough irreversible gel	Forms soft gels which redissolve
Viscosity characteristics (dilute solutions)	Lower, but enormous increase with concn.	Higher, but simple function of concn.
Iodine color	Intense blue	Reddish purple
Enzyme action		
1. α-Amylase	Attacked very slowly. Retrogrades and is then resistant	Readily converted to lower dextrins
2. β-Amylase	Readily converted 95–100% to maltose at low substrate concn., at high concn. retrogrades to resistant form	Converts 52% to maltose, 48% to sol. dextrins
Estimated molecular weight	10,000–100,000	100,000–1,000,000
Complex formation	Complexes with higher alcohols, phenols, acids	No complexes

The ordinary starches such as corn, potato, wheat, and tapioca consist essentially of two types of glucose polymers referred to as amylose and amylopectin. Amylose, which comprises essentially 25% of the starch granule, is a linear glucose polymer united by α-1,4-glucosidic linkages. The amylopectin, which comprises about 75% of the starch granule, is a more ramified branched polymer composed of main chains the units of which are linked by means of α-1,4-glucosidic bonds. However, the branch points consist of α-1,6 linkages with an occasional possible 1,3 linkage. Special starches which are composed entirely of amylopectin are also available to the industry. These are obtained from "waxy" corn and "waxy" sorghum and command premium prices because of the care necessary in growing the grain. Starches with higher amylose contents are also available in limited amounts. A comparison of the properties of amylose and amylopectin is presented in Table III.

Theoretical considerations indicate that a good tub-sizing starch should possess the following properties:

1. A high solubility and low viscosity for a relatively high molecular weight. This is necessary in order that a significant amount of starch can be applied which will penetrate toward the interior (where desired) and have the maximum adhesive strength when it has dried.

2. The starch should not have a tendency to crystallize or retrograde from solution because such starch has little value in a sheet of paper except to limit penetration. Also, insoluble material in a starch solution may be rejected at the entrance to the nip between rolls and such rejected material builds up in the tub

until finally transparent spots may be produced in the sheet.

3. The converted starch should manifest only a small increase in viscosity with decrease in temperature or increase in concentration where optimum penetration into the sheet is desired. This characteristic would be evident in a solution of branched polymer rather than one of a linear polymer which tends to crystallize or retrograde upon cooling.

Comparison of these desirable characteristics with the known properties of separate polymers shown in Table III indicates that the amylose fraction might be undesirable in its natural state because it is colloidally unstable and possesses an extreme tendency to gel or crystallize. It would seem logical, therefore, to choose those modifying or converting agents which preferentially attack the amylose fraction of starch and modify the amylopectin fraction in such a way as to obtain the maximum fluidity with the least loss in adhesive strength. On the other hand, where it is desired that the adhesive be confined to the surface with little penetration, the amylose may serve a useful function if properly controlled.

Acid Hydrolyzed Starches. If cornstarch is suspended in dilute hydrochloric acid solution for a period of time at a temperature below the gel point, it is found that the hot viscosity of the starch cooked in water is lower. It is also found that this treatment increases the amount of butanol precipitable material [as determined by Schoch's method (*38*)] from the normal quantity of 25% to as high as 35%. This indicates an increase in the amylose or linear chain content of the starch. Furthermore, this type of treated starch possesses extreme gelling properties and is even more colloidally unstable than the unmodified original starch. The action of the acid is explained as a preferential penetration of the hydrogen ion into the amorphous regions of the granule as compared to the slower rate of penetration into the crystalline, linear polymer regions. Thus, some of the branches of the amylopectin fraction are preferentially hydrolyzed and these branches become, in effect, linear chains similar to amylose. Because of its colloidal instability, this type of converted product is not suitable for tub-sizing and pigment-coating applications but is sometimes used on fourdrinier kraft board which has a high porosity and requires plugging of the surface. However, if this type of conversion is carried far enough the product loses the tendency to precipitate and gel because of the very low molecular weight. The adhesive strength is then very low.

Dextrinization. When air-dried cornstarch is heated in a metal drum for a period of time at a temperature between 110 and 180°C., the potential viscosity is greatly decreased as a function of time. There are several types of such products sold by the starch industry. Products which have been roasted at a high temperature are called British gums, pyrodextrins, or torrefaction gums. These products are characterized by low viscosity and rather brown color. In other cases prior to the heating treatment a small amount of acid, such as hydrochloric acid, is introduced and the starch product is heated for the desired length of time and temperature. The acid functions as a catalyst and causes a much more rapid breakdown of viscosity; it also shortens the time of heating or lowers the required temperature, whichever may be desired. These milder conditions produce a final product which has a much lighter color and if sufficient acid is added the color may be very light tan, yellow, or almost white. Very little is known of the fundamental structural changes which occur during the heating procedure described above. It is clear, however, that the glucosidic linkages are ruptured to a considerable extent during the heat treatment. Brimhall (*174*) presents evidence which indicates that the heating procedure increases the degree of branching of the whole starch. Apparently, glucosidic linkages in the amylose chains are excited to a sufficient degree that they form a primary valence bond with a neighboring molecule. This produces an additional branching point and prevents this group of molecules from orienting and crystallizing as it would normally do if such a discontinuity of structure did not occur.

The colloidal stability of dextrinized starches is improved considerably. There is very little tendency of the starch solution to gel or crystallize and the viscosity properties are quite stable. Usually these modified starches are partly or entirely cold-water soluble depending upon the degree of modification. Because of their better colloidal stability they are desirable adhesives for tub sizing and machine coating at high solids concentrations. However, poor color is often a problem. The use of pyrodextrins in the clay coating of paper is discussed by Kerr and Schink (*175*). This type of modified starch is the least expensive of the five types.

Oxidation of Starch. One of the most popular types of converted starch used by the paper industry is referred to as oxidized starch although occasionally the terms "chlorinated" and hypochlorite oxidized are used. This starch is most often prepared by suspending pearl or powdered cornstarch in water with a small amount of alkali and adding a desired quantity of calcium or sodium hypochlorite to carry out the oxidation. The quantity of active chlorine will vary between 1 and 15% based on the starch. Several fundamental studies on the course of this type of oxidation have been made, either with sodium hypochlorite or other halogen derivatives. Apparently, all of the possible types of oxidation occur providing the oxidation is carried far enough. See the articles by Felton, Farley, and Hixon (*176*) and Farley and Hixon (*177*) for a discussion of halogen oxidation. These workers demonstrated the types of oxidation which occur and have isolated some of the breakdown products resulting from this process. A great deal of work, however, remains in this field in terms of fully characterizing the course of the oxidation at various conditions of pH, temperature, time, and extent of oxidation. The newer developed techniques such as paper chromatography and paper electrophoresis should simplify this area of investigation a great deal.

Apparently, the sodium hypochlorite oxidation of starch causes a preferential attack on the amylose or linear fraction of the starch. Very soon after the oxidation begins the butanol-precipitable material decreases and finally becomes negligible. This does not mean that the alkaline hypochlorite dissolves the amylose fraction. The yield of such converted starch,

at least up to 10% oxidation, is about 97%. Apparently, the introduction of a few oxidized groups on the linear chains and branched chains in the starch granule prevent the later orientation and crystallization of the dispersed linear fraction. This process, therefore, provides a converted starch of lower viscosity which is colloidally quite stable when it is dispersed in hot water at fairly high concentrations. This type of modified starch has excellent adhesive strength and is a superior surface-sizing and coating adhesive. However, at very high degrees of modification such as may become necessary in high solids machine coating of paper, the hypochlorite-oxidized starches may possess low adhesive strength because of the extensive degree of oxidation necessary for reduction of the viscosity to a suitable level.

A great many other types of oxidizing agents have been utilized for preparing various converted starches. An article by Radley (*178*) covers many of the oxidizing agents which have been used on starch.

Perhaps the best understood type of oxidized starch is a product prepared by reacting the suspended starch with either periodic acid buffered at pH 4.5 or tertiary sodium paraperiodate in acidic solution at pH 4.5. It is well known that such oxidizing conditions preferentially attack the dihydroxy positions at the 2,3-carbon atoms in various carbohydrates. This causes splitting of the pyranose ring at the 2,3 position and leaves an aldehyde group on each carbon atom. At moderate temperatures the pH of 4.5 produces little splitting of the α-1,4-glucoside bond in the main polymer chain. Therefore, the final product has a very high molecular weight and because of the introduction of the two polar aldehyde groups, it also possesses great adhesive strength. When this type of product is dispersed in neutral to slightly acid hot water it forms a superior tub-sizing adhesive for bond-type papers. Wet strength is also produced upon drying the treated product. These uses have been discussed by Jones and coworkers (*179*). However, if this product is subjected to alkaline conditions for any appreciable period of time a serious alkaline degradation of polymer chain occurs and the adhesive strength is quite inferior. Commercial products of this type are presently available but the prices are considerably higher than those of other modified starches.

Enzymatic Modification of Starch. The modification of corn and other starches by means of enzymes is becoming more prevalent in the paper industry today. This modification has several advantages over the others mentioned above. Among these are the relatively low cost, the versatility of the product, and good adhesive properties. In many cases the only additional cost for enzyme modification is the cost of the enzyme.

Almost all modified starches must be cooked prior to their use in the industry and it is only necessary to add the desired quantity of enzyme to cause the modification during the cooking procedure.

Enzyme conversion in the mill permits the paper manufacturer to buy pearl starch and modify this product to any desirable viscosity for tub and calender sizing or pigment coating. Thus, it is necessary to buy only one type of starch whereas with the other types of modification, several products of different degrees of modification must be kept on hand for different processes. It is claimed that enzymatically modified starches have adhesive properties and film flexibility as good as the hypochlorite or dextrinized products. However, to achieve this result it is absolutely necessary to observe certain precautions. Enzymatic modification does have certain disadvantages as follows:

The viscosity of enzyme-converted starches is difficult to reproduce and control at higher solids concentrations. For preparation of pigment-coating adhesives, the conversion may be carried out at 35 to 40% starch solids. The action of the enzyme is heterogeneous and unless the product is very highly converted there is a marked structural viscosity. Mechanical action of pumping or combining the adhesive with a high solids content pigment slurry causes variable breakdown and variable final viscosity. Control of the conversion process at high solids is difficult and requires more expensive equipment and personnel. Many variables affect the conversion cycle and final viscosity. Time, temperature, pH, buffer salts, heavy metal ions, all influence the resultant product. Many mills have installed cam-controlled cooking equipment for better control. In some instances it may be difficult to inactivate the enzyme and arrest the modification at the end of the conversion cycle. Where this occurs the viscosity of the modified product continues to decrease during the time in which the batch of converted starch is used in the process. This is undesirable because eventually the adhesive strength suffers considerably and the paper product will not measure up to its specifications.

General Enzyme Conversion Procedure. The starch is slurried in water at room temperature at a solids concentration of 10 to 40% starch solids. The higher concentrations are those generally used for pigment-coating adhesives. When the starch slurry is uniform, the desired quantity of enzyme (0.5 to 1.0% based on the weight of starch) is added with stirring. Direct steam is then injected into the tank with good agitation. Often, the stirring motor may be turned off when the steam provides sufficient agitation to keep the entire batch of starch in suspension. Injection of steam is continued until the starch reaches a desired temperature, usually about 70 to 72°C. for corn. At the higher starch to water concentrations this temperature produces a stiff gel in the tank and at this point the stirring motor must be turned off to avoid damage. The steam supply is also turned off at this time and the entire mass of gelled starch is allowed to react with the enzyme for a given converting period, usually 20 to 30 min. After about 15 min., the starch gel liquefies and the stirring motor is then turned on to finish the conversion as uniformly as possible. At the end of the converting cycle the steam is again turned on and the temperature is raised to the boiling point for a period of about 10 min. to inactivate the enzyme and prevent further hydrolysis of the starch. The starch dispersion is ready to use at this point or may be diluted to any desired concentration for use.

Some paper companies prefer to add the enzyme at the moment the starch reaches the gel point. This may save about 10% of the enzyme but frequently mixing difficulties and greater heterogeneity of conversion is encountered with this procedure. It is clear that the enzymes will not act effectively on ungelatinized or poorly gelatinized starch. Apparently, this is caused

by the slow diffusion of the enzyme into the starch granule.

Other converters prefer to add larger quantities of enzyme at the beginning of the cycle and continue raising the temperature through the gel point right on up to the boiling point of the starch. The extra enzyme carries the conversion through the gel stage sufficiently rapidly that no solid gel forms. This procedure can be used at 25% starch solids or less but difficulty is encountered at higher concentrations. The optimum pH for most of the enzymes supplied to the paper industry is between 6 and 7, but the pH should not be allowed to remain over 7 for any significant part of the converting cycle. If the mill water pH is high or low, calcium carbonate or acid or basic phosphates are added to buffer the water.

Difficulty with inactivation of the enzyme may be eliminated sometimes by the addition of sufficient organic acid to lower the pH to 5 at the high temperature used in the latter cooking stage of the converting cycle. The low pH value inactivates the enzyme very rapidly at temperatures in the neighborhood of 90 to 95°C. For very high solids coating colors where the quantity of water which can be present in the final mixture is very limited, some companies prefer to convert the starch in the presence of the clay pigments. This procedure requires special handling because of the adsorption of the enzyme by the clay surfaces. See an article by Hughes and Craig (*180a*).

Source of Enzymes for Starch Conversion. An enzyme may be defined as a biochemical catalyst. It consists of an organic molecule attached to a proteinlike group. The organic molecule has the ability to temporarily attach itself to a material and break a chemical bond at a lower temperature or energy level than would otherwise be possible.

The enzyme is able to make many attachments and disconnections but after a time the molecule apparently loses the ability to break away from the substrate molecule and can no longer function as effectively. It is then said that the enzyme becomes inactivated or in some cases poisoned. Generally speaking, enzymes are specific and there are very many of them found in nature. The starch-modifying enzymes are called amylases. Only two classes of the amylases are of any great importance to the paper converter. These are called α-amylase and β-amylase. Suitable products for starch conversion may be purchased from various suppliers under names such as Amyliq, Vanzyme, and Rhozyme.

A pure α-amylase enzyme is capable of attacking the starch polymer chain at random at the α-1,4 linkage. A short time after such action begins the starch is reduced to lower molecular weight dextrins. The viscosity in this condition is quite low compared with the original product. This action is simply an hydrolysis which occurs in a very random manner, and therefore, produces a large decrease in molecular weight in a short time. It has been well established that the α-amylase will reduce the viscosity of a starch paste much faster than β-amylase enzyme.

The β-amylase enzyme is often called saccharogenic because it produces sugars. This enzyme is capable of attacking the high-polymer glucose molecule only at the nonreducing end and it hydrolyzes off two glucose units at a time in the form of α-maltose. This action, of course, progressively degrades the chain. However, because the action must begin at the very end of the molecule, the viscosity does not decrease nearly as rapidly with chain scission as is the case with the α-amylase random attack. In other words, to obtain a low viscosity it is necessary to develop a great deal of maltose in the final product. Maltose has very little, if any, adhesive strength and, therefore, is wasted insofar as a tub-sizing or coating adhesive is concerned. Moreover, the β-amylase enzyme action is restricted to the α-1,4 linkage and cannot bridge over a branch point in the molecule. Therefore, when the enzyme has hydrolyzed off the maltose residues up to a branch point, the action stops and a high molecular weight dextrin remains as the final product. In order to bridge over the branch point in the molecule it is necessary to incorporate an additional enzyme such as α-glucosidase. As soon as the branch point has been bridged the β-amylase is again able to hydrolyze the product to a lower viscosity plateau. It is clear, however, that the α-amylase enzyme is superior for converting starch for adhesive purposes.

The enzymes used for converting starch are obtained from the higher plants such as cereals and grains after the seeds have been sprouted, from microbes such as fungi and bacteria, and from animal glands such as the pancreas obtained from slaughterhouses. All of them are mixtures of enzymes which are treated by the manufacturer to favor α-amylase activity.

Derivatized Starches. The tendency for most converted starches to gel and increase greatly in viscosity at lower temperatures led to the development of the derivatized starches. These products are made by reacting starch under alkaline conditions with ethylene oxide until the desired degree of substitution is attained. The reaction occurs on both the hydroxyl groups of the starch and on the hydroxyl groups at the end of the attached ethylene oxide. This produces ethylene oxide chains which are bulky and prevent retrogradation of the amylose fraction of starch when it has been dispersed in hot water. The product has high film strength and good clarity of film. This treatment does not appreciably lower the hot viscosity of the starch. Therefore, it is necessary to dextrinize or oxidize the starch either before or after the derivatization. Although these products are somewhat more costly than some of the other converted starches their superior properties for surface sizing have made them quite popular.

Mixtures of Surface-Sizing Agents. A great many other surface-sizing polymers are used on paper and paperboard. Among these are methylcellulose, carboxymethylcellulose, hydroxyethylcellulose, sodium and ammonium alginates, various gums, polyvinyl alcohol, wax emulsions, Aquapel, Quilon, Scotchgard, and many others. Mixtures of these materials with various starches are commonly used to achieve desired surface effects.

Aquapel (Hercules Powder Co.) is an alkylketene dimer which produces outstanding resistance to surface penetration of aqueous liquids at levels of application of 0.5 to 2 lb. per ton of paper. This material is believed to react with the cellulosic hydroxyls on the surfaces of fibers. Quilon (E. I. du Pont de Nemours and Co., Inc.) is a stearato chromium chloride also

used for imparting water resistance. Scotchgard (Minnesota Mining and Manufacturing Co.) is a similar chromium complex containing a perfluorocarbon acid. This material has a sufficiently low free surface energy that it is able to impart grease resistance in porous paper and board products.

ADDITIVES FOR COMBATTING FOAM TROUBLES IN PAPERMAKING

The Foam Problem

Foam troubles are encountered sporadically in the following places in papermaking:

1. Pigment coating of paper, where troubles are more frequently encountered in conversion coating than in machine coating. The reason for this is that proteins are more frequently used as the adhesive in conversion coating and proteins are often excellent foam stabilizers.

2. Surface sizing of various papers with glue, modified starch, or resin dispersions. Here, air is continuously worked into the dispersion and antifoams are often necessary.

3. Paper machine operation, where (a) the foam may consist of large bubbles which cause sizable thin areas in the sheet and, in extreme cases, significant fiber losses, or (b) the foam may consist of very small bubbles which interfere with drainage on the wire and which cause pinholes and poor "formation." The latter type of foam is often unsuspected by the machine operator. Indirectly, this type of foam may actually limit production. Also, foam causes beater overflow, reduced beater circulation, stock pump binding, uneven consistency, and poor internal sizing.

4. Deinking of papers. Many of the materials normally employed or encountered in the deinking of paper are good foam stabilizers and it is often necessary to add antifoam agents to the operation.

5. Black liquor recovery. Serious foaming occurs during this operation with both sulfate and soda process liquors although the former type is often more troublesome. The trouble is greater at low solids concentration and becomes insignificant above 35 to 40% solids.

In general, antifoams are used in the range of 0.01 to 1.0% based on the fiber in papermaking operations, and 100 to 1000 p.p.m. in coating operations.

Nature of Foam

Foams are composed of small bubbles of gas dispersed in a liquid medium by vigorous agitation. The process of dispersion requires a considerable amount of energy which is stored in the surface of the gas bubbles. It is a fundamental law of thermodynamics that such systems revert to a state of minimum energy; this natural tendency therefore causes coalescence and collapse of the bubbles in the liquid.

Foaming represents a state of competition between two rate processes, namely, the rate of foam formation, and the rate of destruction or collapse of the foam. The collapse of bubbles is delayed or prevented by surrounding each bubble with a filmlike membrane which resists puncture and coalescence by other bubbles and external forces. Thus, a *pure* liquid does not form a stable foam because no opportunity exists for the formation of a stabilizing film. The addition to the system of a third component which is capable of being absorbed at the gas-liquid interface will, however, furnish a protective film around each bubble.

Such films may be formed in at least two ways: (1) through the action of surface-active agents and (2) through the concentration of finely divided solid materials around each bubble.

Surface-active agents are exemplified by the salts of rosin and fatty acids present in sulfate soap and by the many synthetic detergents and soaps used in our homes. Hence, the source and quality of the mill water supply is important. Industries and communities upstream have a marked effect upon the nature and extent of contamination of the water. Spent sulfite liquor, kraft black liquor, washing compounds, etc., may greatly increase the tendency of the water to foam. Many mills on small rivers are encountering foam problems where very little or no trouble existed previously. Possibly some of these foam problems result from the rapidly increasing use of household synthetic detergents.

Synthetic detergents are scientifically designed for high surface activity and chemical stability and most of them are good foam stabilizers. (An exception to this is the nonionic surfactant especially designed for low foaming.) The annual production of surfactants has increased during the last few years from 402 million-lb. to 1.5 billion lb. Increasing quantities of these materials are finding their way into many industrial water supplies. Furthermore, these surface-active agents are not easily removed from waters which are passed through domestic sewage disposal plants and they cause considerable trouble in water-treatment plants by stabilizing the flocculation system.

The second means for stabilizing foams, that is, the finely divided solid, is present in most papermaking systems to various extents in the form of fine particle size clays and other pigments, dyes, fiber fines, resinous and lignin components in groundwood, alumina floc, and various sizing materials. Under normal conditions the rate of foam collapse in the presence of these materials precludes the accumulation of foam unless some other stabilizing factor is introduced into the system or an unusual amount of air is incorporated into the stock. In this regard excessive churning of the stock with air at leaky pumps, jordan inlets and outlets, and mixing boxes tends to increase foaming and should be avoided.

Where stabilizing factors are present and foam has an appreciable time of existence, the protective layer surrounding each bubble drains, becomes thinner, more fragile, and eventually breaks and the bubble collapses. Certain materials have a marked effect upon these properties of the film and therefore upon the accumulation of foam. Brown, Thuman, and McBain (*181*) have shown that the surface viscosity of certain surfactant solutions are very high. For example, the plastic viscosity of a film of lauryl alcohol is 2.5×10^5 surface poises, as compared to the bulk viscosity of 0.2 poise at 25°C. This is attributed to the effect of surface orientation which produces coherence in the monolayer. These investigators (*182*) have also shown that gas permeability of the film is also an important factor in foam stability.

Materials which shorten the life of the bubbles are called antifoam agents or foam killers. The materials used are kerosene, higher alcohols, and complex mixtures of hydrocarbons, fats, and other glycerides compounded on the basis of trial and error for a specific purpose. Sometimes in the past the cure from some of the latter materials was worse than the foam trouble. Plugging of wires and "fish eyes" developed in the sheet. Today, it is gradually becoming possible to analyze a foam problem in terms of the interfacial energies involved and determine the type of antifoam agent which should work best under a given set of conditions. It must be pointed out, however, that some foam problems still do not respond completely to this treatment.

Theory of Foam Inhibition

Many years ago Edser noted that the rupture of a soap bubble occurs at a velocity of 20 to 50 m.p.h. and that certain oils such as triglycerides and oleic acid spread at interfaces at about the same speed (Edser, 1922). This observation led to the suggestion that spreading of a droplet of antifoam could be considered equivalent to a rupture in the stabilizing film.

Ross (*184*) subsequently showed that effective antifoam agents spread on the surface of the liquid film before it ruptures.

Robinson and Wood (*183*) were probably first to describe in detail, a mechanism of bubble coalescence. However, this has been improved and extended considerably by Ross (*184*).

Under suitable conditions droplets of the antifoam are drawn by surface-tension forces into the liquid film between bubbles. This occurs if

$$\gamma_F + \gamma_{D'F} > \gamma_D$$

where γ_F is the surface tension of the foaming liquid, γ_D that of the antifoam agent and the prime marks refer to the condition where the liquid is saturated with the other.

An "entering coefficient," E, is defined as follows:

$$E = \gamma_F + \gamma_{DF} - \gamma_D$$

where $E > 0$ the antifoam is drawn into the liquid film and bridges between two air bubbles. When $E < 0$ the antifoam is ejected from the liquid film if it contacts.

Following Harkin's idea of spreading coefficients there may be defined three entering coefficients.

$$\begin{aligned} (1)\quad E_{DF} &= \gamma_F + \gamma_{D'F'} - \gamma_D \\ (2)\quad E_{D'F} &= \gamma_F + \gamma_{D'F'} - \gamma_D \\ (3)\quad E_{D'F'} &= \gamma_{F'} + \gamma_{D'F'} - \gamma_D \end{aligned}$$

The initial entering coefficient exists when the antifoam is first added to the foaming system, and the semi-initial coefficient (*182*) exists when the drops of antifoam have become saturated with the foaming liquid. Usually the numerical values of the initial and semi-initial entering coefficients do not differ much from one another. The final coefficient exists when both phases are mutually saturated.

Now the antifoam will spread on the foaming liquid if

$$\gamma_F > \gamma_{D'F'} + \gamma_D.$$

The Harkin's spreading coefficients, S_{DF}, are

$$-\left(\frac{\partial F}{\partial S}\right)_{P,T} = S_{DF} = \gamma_F - \gamma_{D'F'} - \gamma_D$$

$$S_{D'F} = \gamma_F - \gamma_{D'F'} - \gamma_D'$$

$$S_{D'F'} = \gamma_{F'} - \gamma_{D'F'} - \gamma_D'$$

Calculation of the free-energy changes shows that when S_{DF} is positive the antifoam will spread as a *duplex film* upon the foaming liquid. Such duplex films are unstable and will soon form a lens of liquid in equilibrium with a monolayer film. This change occurs when the initial spreading coefficient changes to the final spreading coefficient, i.e., when the two liquids are mutually saturated. The final spreading coefficient is always negative.

The relation between the entering and spreading coefficients are as follows:

$$\begin{aligned} E_{DF} &= 2\gamma_{D'F'} + S_{DF} \\ E_{D'F} &= 2\gamma_{D'F'} + S_{D'F} \\ E_{D'F'} &= 2\gamma_{D'F'} + S_{D'F'} \end{aligned}$$

It may be seen that it is possible for the entering coefficient to be positive and the spreading coefficient to be negative. This would occur with pairs of liquids having high interfacial tensions. A different situation exists where liquids have relatively low interfacial tensions. Here, the entering and spreading coefficients are approximately equal.

The mechanism of film rupture occurs as follows:

1. Entering—E must be positive so the antifoam is drawn into the liquid film between bubbles.
2. Spreading—S must be positive so after the drop has become part of the film it will spread as a duplex film on each side of the original film between bubbles.
3. Rupture—as the antifoam spreads in the form of two duplex films, the original droplet thins out, drawing the two bubbles closer together. This squeezes out the original liquid from the film. Finally, a thin spot occurs where the antifoam droplet originally entered.

Simultaneously, the duplex film of antifoam lowers the surface tension inside the bubble (because γ_F must be $> \gamma_D$). This increases the radii of curvature of the bubbles which further decreases the thickness of liquid film between them. The total effect replaces a unit of stable liquid film with a liquid film that is unstable. "The film is thinnest precisely at the place where it is composed *entirely* of antifoam and here rupture can be expected."

The final spreading coefficient is always negative. Thus, if the two liquids F and D become mutually saturated, the liquid D does not enter the liquid F at all; or, having entered, it does not spread as a duplex film. This predicts that a good antifoam agent must eventually lose much of its antifoaming effectiveness in a closed system. This is often found to be the case.

Determination of Foam in the Papermaking System

It is often desirable to determine the amount of foam in the paper stock. This permits estimation of the problem and often locates the difficulty if the tests are performed on stock taken from various parts of the system. The effectiveness of antifoam treatments may also be determined. Numerous tests have been devised for the purpose. TAPPI Routine Control Method 173 involves weighing a given volume of the stock before and after deaeration of the stock by boiling for a given time Holland (*185*) criticizes this method and proposes a combination measurement of

the degree of flotation of the stock and volumetric determination of the amount of air present. Both Holland (*185*) and Hollaender (*186*) outline procedures for the study of the relative effectiveness of antifoams for a given stock system. Gavelin (*187*) states that gas generated from supersaturated systems is much more detrimental than entrained air upon formation and drainage and he proposes the use of drainage testers for evaluating this behavior. Green and Leaf (*188*) studied the compounds of jack pine groundwood which produce foam. A foam fractionation apparatus is described which permits isolation of the surface-active components.

Boadway (*189*) has presented an interesting discussion of gas in papermaking stock and its determination. The considerations led to the development of the Vorvac system for gas removal by Freeman and Boadway. The Vorvac is a modified Vortrap and is described in (*190*) and (*191*). The Deculator, a vacuum tank for stock deaeration, is described by Clark and Vicario (*192*) and Smith and Stewart (*193*).

ADDITIVES WHICH AFFECT OPTICAL AND PRINTING PROPERTIES OF PAPER AND PAPERBOARD

Fillers and Loading Materials

The terms filling and loading refer to the process of incorporating mineral pigments into paper or paperboard during papermaking. This process is distinguished from pigment coating of paper products which involves application of a layer of pigment and adhesive to the surface of the sheet after it is formed.

The use of fillers is said to have begun many years ago in England when a papermaker found he could add cheap clay to his pulp and sell the paper for the same price as the unfilled paper. At first pigments were considered as adulterants, but printers soon discovered that the filled sheet possessed better printing properties. This led to a demand for pigment-filled papers and a search for brighter and better pigments. Today, a wide variety of such fillers and loading pigments are used for making many grades of paper and boards. Among the pigments used are clays, calcium carbonate, talc, calcium sulfate, titanium dioxide, barium sulfate, calcium silicates, zinc sulfide, diatomaceous earth, and luminescent pigments. The estimated annual consumption for some of these pigments is given in Table I.

Effects of Pigments on Paper Properties. Pigments are used in amounts varying from 2 to 40% of sheet weight and the majority of papers contain between 4 and 15%. Suitable pigments improve brightness and opacity, basis weight, softness, smoothness, finish, and ink absorption (printing) properties. In general, less pitch trouble is encountered in a higher filler content furnish. On the other hand, fillers lower internal sizing and invariably reduce those strength properties which depend primarily upon fiber-to-fiber bonding. Tearing strength is sometimes an exception at low filler contents. The detrimental effect on strength and retention difficulties are perhaps the two greatest problems encountered in the use of fillers.

Optical Properties of Pigments and Papers. The more important properties of several filler pigments are listed in Table IV.

The brightness of paper may be defined as the reflectance of a pile of many layers so thick that no change in reflectance occurs if the backing material is changed from black to white. The brightness value is often given the symbol R_∞ and is obtained with a standardized instrument which utilizes the blue portion of the spectrum.

Table IV. Some Typical Properties of Several Filler Pigments

	Clay	*Calcium carbonate (precipitated)*	*Titanium dioxide*	*Zinc sulfide*
Brightness, %	75–85	95	98	98
Refractive index	1.56	1.56	2.55–2.70	2.37
Av. particle size, μ	0.5–1	0.2–0.5	0.3–0.35	0.3
Valley abrasion, mg. wire loss	15–20	0.6–4	20–30	Low
Specific gravity	2.5–2.8	2.7–3.0	3.9–4.2	4.0
Solubility, g./100 g.				
in H_2O	Negligible	0.0014	Negligible	Negligible
in diluted acid	Negligible	Soluble	Negligible	Soluble
Cost, cents/lb.	0.6–1	7–9	25–28	25–26

The Kubelka-Munk theory (*194*) relates light reflectance to the transmittance of translucent media. This theory has been applied to paper by Steele (*195, 196*), Judd (*197, 198*), and Van den Akker (*199*). Van den Akker showed that the diffuse reflectance of paper may be expressed in terms of the specific scattering coefficient, s, and the specific absorption coefficient, k, by

$$R_\infty = 1 + (k/s) - \sqrt{(k/s)^2 + 2(k/s)} \qquad (25)$$

and from this

$$k/s = (1 - R_\infty)^2/2R_\infty \qquad (26)$$

Equation (26) shows that R_∞ depends only upon the ratio k/s. The specific scattering coefficient is also related to R_0, the reflectance of a single layer of paper over a black cavity, and W, the basis weight by

$$R_0 = \frac{\exp[sW(1/R_\infty - R_\infty)] - 1}{(1/R_\infty)\exp[sW(1/R_\infty - R_\infty)] - R_\infty} \qquad (27)$$

or, sW is related to R_∞ and R_R', the reflectance of a single layer over a backing of absolute reflectance R' by

$$R_{R'} = \frac{(R' - R_\infty)/R_\infty - R_\infty(R' - 1/R_\infty)\exp[sW(1/R_\infty - R_\infty)]}{(R' - R_\infty) - (R' - 1/R_\infty)\exp[sW(1/R_\infty - R_\infty)]} \qquad (28)$$

Van den Akker (*199*) has shown that the scattering power, sW, defined on a weight basis is related to the scattering power on the thickness basis by

$$sW = SX \qquad (29)$$

where

S = the scattering coefficient
X = the thickness of the layer, and
W = the basis weight or weight per unit area.

By definition, S is the fraction of light incident upon an infinitesimally thin layer in the material that is scattered backwards by that layer, divided by the thickness (infinitesimal) of the layer. The specific scattering coefficient, s, is similarly defined in terms of basis weight instead of thickness because basis weight is more easily

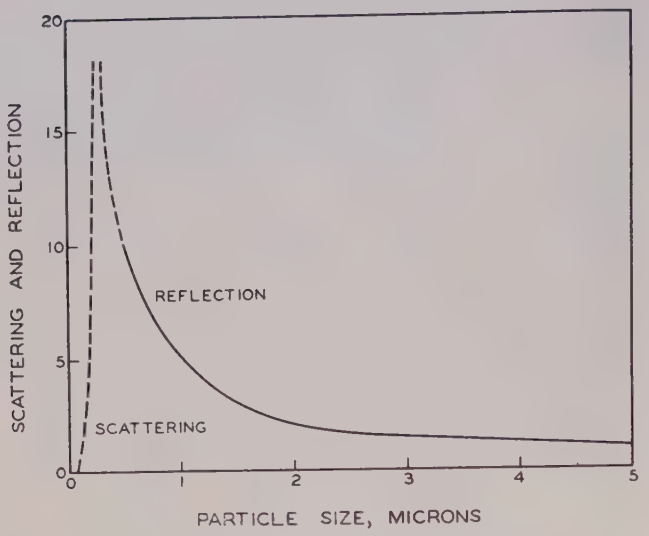

Fig. 19. Effect of pigment particle size on the scattering and reflection of light [From Sawyer (210)]

measured with accuracy than caliper of paper. The calculations involved in obtaining s values are quite laborious but Judd (*197*, *198*) has prepared a chart which relates R_0, R_∞, SX, and TAPPI opacity. Thus, if any two measurements such as R_0 or R_∞ are made, SX can be read from the chart and by equation (29) SW may be calculated. When the basis weight is known, s is readily obtained.

Parsons (*200*) observed that the value of s in unfilled sheets is directly proportional to the surface area available for scattering light provided the size of the fibers is not too small. (Fiber fines differ considerably in chemical composition which also changes k.) Thus, if the specific scattering coefficient of an unbonded sheet, s_u, is known, the percentage bonded area may be determined from the specific scattering coefficient of the bonded paper, s_b, by

$$\frac{s_u}{s_b} \times 100 = \text{Bonded area, \%} \qquad (30)$$

This technique has been used by Ratliff (*201*), Keeney (*202*), Haselton (*203*), Leech (*48*), Nordman (*204*), and others in studies of relative bonded area of papers. The direct relationship between the specific scattering coefficient and exposed fiber surface area determined by nitrogen adsorption has been demonstrated by Haselton (*203*, *206*) and Swanson and Steber (*207*).

Adrian (*208*) developed a method which permits determination of s values for pigments in the absence of paper. The value of s for a given material depends upon the number of light-scattering points per unit volume, particle size and shape, and the difference between the indices of refraction of the particle and its surrounding medium.

When the specific scattering coefficients of the pulps, fillers, and any colored pigments are known, the scattering power of the filled paper may be obtained from

$$sW = s_1W_1 + s_2W_2 + s_3W_3 \ldots + s_nW_n \qquad (31)$$

where W_1, W_2, W_3, etc., are the weights per ream of materials which have specific scattering coefficients s_1, s_2, s_3, etc., respectively. Van den Akker (*209*) has pointed out that best results are obtained when the various specific scattering coefficients have been determined from sheets of similar furnish and degree of beating.

A similar relationship holds for the light-absorbing power of a filled paper,

$$kW = k_1W_1 + k_2W_2 \ldots k_nW_n \qquad (32)$$

where k, k_1, k_2, etc., are the specific absorption coefficients of the filled paper and each of its components, respectively. The quantity, kW, is strongly influenced by coloring materials in the sheet. Also, the individual k values should be determined for similar furnish and degree of beating because it is well known that the apparent tinctorial power of a dye depends upon the nature of the pulp and the degree of beating.

It becomes apparent from these considerations that the ability of a white pigment to improve brightness of a paper depends upon its surface area available for scattering light and its refractive index. Because the specific surface area increases with decreasing particle size, it is important that white pigments have a small average particle size. However, an optimum particle size exists for scattering and reflecting light. This is illustrated in Fig. 19 taken from Sawyer (*210*). The best particle size occurs at approximately one half the wavelength of light used for observation. This is the reason that many of the manufactured pigments have particle sizes in the 0.25 μ range. It should be clear, of course, that when two pigments have the same particle size, the one of higher refractive index will scatter more light.

White pigments which have brightness values greater than the pulp will increase the brightness of paper for two reasons. First, the pigment in the sheet increases the surface area available for scattering of light. Secondly, the pigment decreases fiber-to-fiber bonding thereby increasing the external fiber surface area which scatters light.

Opacity, in the paper industry, is determined in the following two ways:

$$R_0/R_\infty = \text{printing opacity} \qquad (33)$$

$$R_0/R_{0.89} = \text{TAPPI opacity} \qquad (34)$$

where $R_{0.89}$ is the reflectance of a single layer of paper over a white body which has an absolute reflectance of 0.89 when the paper is in place. Both expressions for opacity are related to their component terms by the Kubelka-Munk equations (*27*, *28*) and the Judd charts (*198*) and TAPPI Data Sheet 65 are useful for any calculations involved. Equations (31) and (32) may be used to study the effectiveness of fillers as opacifying agents. With simple furnishes and known weights of fillers, the specific scattering coefficients of the several fillers (in the environment of the paper) may be calculated and compared (*209*). In work of this type it should be remembered that a filler of inferior brightness can improve opacity of paper by increasing kW of the sheet. The more ideal situation is obtained when opacity is improved through large scattering power, sW. This is the usual case.

When a paper is impregnated with waxes, oils, greases, etc., which make optical contact with fibers and fillers, the specific scattering coefficients decrease to much lower values. Under such conditions, fillers with low refractive indices such as clay, calcium car-

bonate, talc, and calcium silicates impart no improvement in opacity. However, the higher refractive index pigments such as titanium dioxide and zinc sulfide do impart opacity to such impregnated papers.

Retention of Pigments in Papers. The retention of pigments has long been a problem in papermaking. Where closed white water systems exist and lower levels of addition of inexpensive pigments are employed the problem may not be economically important. However, poor retention usually coincides with marked two-sidedness of papers (a condition wherein the wire side of paper contains less pigment than the felt side). Where expensive pigments are used poor retention is costly.

Numerous pigment properties seem to affect retention. Among these are solubility, specific gravity, particle shape, particle size, and degree of dispersion. Other substances added to the system markedly affect retention. Many of these properties have the obvious effects. The solubility of most pigments is negligible but calcium sulfate is appreciably soluble and, what is even more important, it has a negative solubility coefficient with temperature. Increases in temperature of the machine system will cause deposition of calcium sulfate in pipe lines. Calcium carbonate is also soluble in acidic furnishes and should not be used under these conditions. Even temporary low pH values used for flocculation of a wax sizing emulsion will dissolve calcium carbonate and lead to foam troubles in the system. The high specific gravity of barium sulfate (about 4.5) causes poorer retention of this pigment.

The addition of rosin size in itself, has no effect on retention but when the alum is added the combination improves retention, probably by flocculation of the pigment.

Unmodified starch used as a beater adhesive along with alum may improve retention, but chemically modified starches, such as those which are oxidized with sodium hypochlorite, seem to reduce retention of pigments substantially. Willets (*210*) first observed this behavior of starches on titanium dioxide "one pass retention" in 1935 and suggested that the effect of starch was due to its protective colloid action. Brill (*212*) studied various retention aids for titanium dioxide filler in the presence of chlorinated (oxidized) cornstarch. He concluded from his studies that:

1. All the starches, in all modifications tested, reduced the retention of titanium dioxide.
2. Dry addition pearl starch reduced retention of the pigment to the least extent.
3. The cooked, oxidized starches were some of the worst offenders in reducing retention of the pigment. Even 0.1 to 0.25% of this starch lowered retention markedly.
4. The soap precipitated pearl (starch) gave the greatest physical strength improvement but some of the oxidized starches were very close seconds.

Pigment preflocculation with alum before addition to the furnish or addition of sodium aluminate or sodium phospho aluminate gave better retention in the presence of starch, but not as good retention as they did in the absence of starch. Animal glue (*214*, *215*) increased retention, but its effect was reduced considerably in the presence of starch. Potato starch improved retention but its effects were reduced when oxidized starch was also present. Cationic starch improved retention even in the presence of 2% of oxidized starch.

Brill and Hecklau (*213*) studied the effects of various processing factors on retention and optical efficiency of titanium dioxide. They found that severe agitation, such as refining, markedly reduces the retention of titanium dioxide if starch is present but not in the absence of starch. Retention increases as the time between flocculation and the wire is increased in the absence of starch, but a loss in retention occurs with time if starch is present. Simultaneous addition of clay and titanium dioxide did not affect titanium dioxide retention in the presence or absence of starch. Starch has a greater effect on retention of titanium dioxide than on clay. Dilution of the furnish after flocculation had little effect on retention either in the presence or absence of starch. Temperature had little effect. The optical efficiency of titanium dioxide was seriously impaired by excessive flocculation such as obtained with the new acrylic acid-type flocculating agents. A slightly flocculated pigment, however, was optically more efficient than a dispersed pigment.

The cost of titanium dioxide and zinc sulfide pigments has led to the development of several new polymer retention aids. Chemically, these materials are based on high molecular weight acrylamides (*216*) or sodium salts of polyacrylic acid. Laboratory and mill data show increased retention from former values of 50 to 60% to 80 to 90%. The nonionic materials are claimed not to flocculate the cellulose fibers (*216*).

In using the polyacrylamide type materials as retention aids it is important that alum addition and pH adjustment of the furnish containing the filler be done before the dilute polymer solution (0.05%) is added. After the polymer is well distributed, excessive agitation should be avoided (*217*). Maximum activity of the retention aid depends upon the pH and alum concentration. With alum additions of 2 to 3% on the fiber, a pH around 6 is desirable. The polymer and alum appear to attach the pigment particles to the fiber surfaces by a chemical linkage (*217*). The nature of this linkage has not been described but it probably involves a coordination with aluminum and olation in a manner similar to that of rosin sizing. The polyacrylamides also increase drainage rate considerably at low levels of addition (1 lb. per ton) (*217*). A comparison of two polymers of different molecular weights in machine trials has been made by Date, Shute, and Shand (*218*). The mannogalactan gums are also used as retention aids (*21*).

Mechanisms of Retention. There are essentially three mechanisms of retention of fillers in paper. These may be described as (1) the filtration theory whereby filler particles which are larger than the openings in the forming paper web are simply filtered out of the slurry; (2) the colloidal or coflocculation theory wherein the filler particles and fibers coflocculate under the influence of long-range surface forces and the particles are then held to the fiber surface by similar forces; (3) the mechanical theory wherein the filler particles are embedded within the fibers during beating or refining or are trapped in the fiber lumen. The last mechanism is believed to be relatively unimportant.

The nature of the papermaking process leads to the conclusion that filtration must be an important part of

the retention mechanism for any pigment. Relatively coarse pigments may be retained almost entirely by filtration. However, well-dispersed pigments, on the other hand, are poorly retained in the absence of flocculating effects and it is well known that such pigments easily pass through the pores of filter papers. It is believed that the Derjaguin-Verwey-Overbeek theory of colloidal stability (*147*) is directly applicable to filler retention. The application of this theory to the dispersion and coagulation of kaolin clays has been studied by Hemstock and Swanson (*219*) and by Holtzman (*220*). According to this theory, the stability of any multiphase system, in which one or more of the phases possesses a high total free surface energy, depends upon the relative magnitude of two potentials, the attractive potential due to the long-range Van der Waals' forces, and the repulsion potential due to the electrical double layer which surrounds the charged particles. The attractive potential energy V_A, between two parallel platelike particles which are much thicker than their distance of separation is, according to Verwey and Overbeek (*147*),

$$V_A = -\frac{A}{48\pi d^2} \qquad (35)$$

where A is a constant characteristic of the chemical composition and lattice structure of the mineral and d is one half the distance of separation of the plates. The repulsion potential between two such particles, on the other hand, is very dependent upon the composition of the system, particularly the pH and ionic strength of the interparticle fluid. Verwey and Overbeek derived the following equation for the repulsive potential energy, V_R, between two parallel plates, each one square centimeter in area, when the electrical double layer interaction is not very extensive.

$$V_R = \frac{32nkT\gamma^2}{X}(1 - \tanh Xd) \qquad (36)$$

where n is the number of ions of opposite charge to the particles contained in 1 cubic centimeter of intermicellar solution, k is the Boltzman constant, T is the absolute temperature, X is a parameter related to the reciprocal of the effective thickness of the electrical double layer, d is one half the distance of separation of the plates and

$$\gamma = \frac{\exp(Z/2) - 1}{\exp(Z/2) + 1} \qquad (37)$$

and where Z is

$$Z = \frac{V\epsilon\psi_0}{kT} \qquad (38)$$

in which V is the valence of the counterions, ϵ is the charge on the electron, and ψ_0 is the potential existing between the surface of the particle and intermicellar solution. The parameter X in equation (36) is more precisely defined by

$$X = \sqrt{\frac{8\pi n\epsilon^2 V^2}{DkT}} \qquad (39)$$

where D is the dielectric constant of the intermicellar solution.

Because ψ_0 had never been measured for the kaolinite-water system it was not possible to apply the Verwey-Overbeek theory to this system in a quantitative manner. However, as pointed out by Holtzman (*220*), this measurement may be obviated if the surface charge density of the particle σ is known. Verwey and Overbeek have related σ to the parameter Z by the following equation

$$\sigma = \frac{2nDkT}{\pi} \cdot \sinh\frac{Z}{2}$$

Holtzman (*220*) measured the anionic adsorption by purified kaolinite, particle surface area, and equilibrium composition of the intermicellar solution and calculated the repulsive potential energies at various interparticle distances. He was able to show how these potential energies change as dispersing agents or other salts are added to kaolinite suspensions in water. This information is not only useful to those interested in filter retention but also to those interested in peptizing kaolin clays at high solids content for pigment coating of paper.

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The Science of Paper Manufacture

P. E. WRIST

It is only possible in a survey of the manufacture of paper such as this to touch briefly on a few of the aspects of the process. Papermaking originated as a craft industry, and today the operation of the modern high-speed machine still depends to a very large extent on the craftsmanship of its operators. Over the past century these papermaking skills have been complemented by a rapidly expanding technology which today permits large volume, continuous high-speed production. Our understanding of the scientific principles underlying the process has not kept pace with these advances and in many areas it limits our further development. An active interest is now being shown by many workers in this field of science and I would like to talk about some of their work today. In doing so I will avoid as far as possible topics of an essentially technological nature and try to emphasize the basic concepts underlying the process.

Papermaking consists of eight basic operations:-

1. Fiber pretreatment,
2. Fiber blending,
3. Furnish cleaning and screening,
4. Slurry distribution and metering, and fiber dispersion,
5. Web formation, with water removal by filtration,
6. Web compaction, with water removal by mechanical pressing,
7. Web drying, with water removal by heat and evaporation,
8. Sheet finishing, by one or more of the following:
   a. Calendering
   b. Sizing
   c. Coating
   d. Creping
   e. Glazing, etc.

In the original handmaking process each one of these operations was performed individually, very often by the same person. Many modern machines perform all eight continuously in a single integrated system.

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Scientific studies of the principles involved in the above operations are of obvious commercial interest to the paper industry. Many of the problems and principles involved are of wider interest. Some have features in common with similar operations in other industrial processes. Others are interesting for purely academic reasons, the fiber suspension or paper web merely providing an illustrative example of a general principle.

FUNDAMENTALS OF PAPERMAKING FIBERS

An understanding of the morphology and of the chemical composition of the individual fibers from which a paper sheet is made helps in our understanding of the papermaking process itself. Wood provides most of our papermaking fibers and as a result most of our information is concerned with fibers from this source. The type of wood, the climatic conditions during its growth, the pulping process used to isolate the individual fibers, the bleaching sequences and finally the hydromechanical treatment all effect the way in which the resulting fibers will behave in suspension, how water will drain from them and the properties of the wet and of the dry webs formed from them.

Microscopical studies of wood and wood fibers have given us a fairly consistent picture of the physical structure of the fiber (Fig. 1). The fibrilla components of the fiber, which are the most readily distinguishable features under the microscope, are arranged in four distinctive walls. The organization of the microfibrils within these layers largely determines the physical properties of the fiber. The outer primary or P wall is the first to form. It is generally agreed to consist of a very loosely woven fibrous network, lower in cellulose content than the rest of the fiber and infused with nonfibrous residues from the middle lamella which separates the individual fibers from one another. It

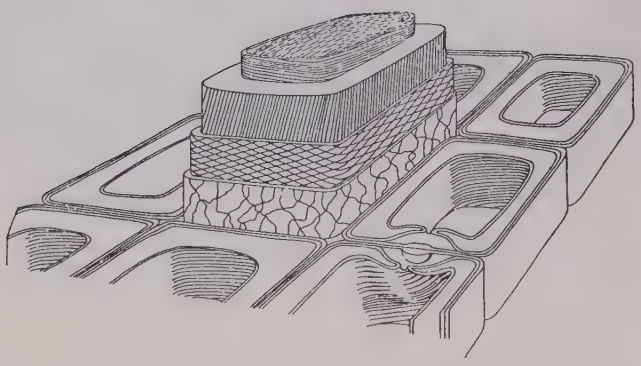

Fig. 1. Organization of a spruce tracheid cell wall (1)

contains the fiber pits and their membranes. The next inner wall, S_1, is made up of several (possibly four) layers of spirally arranged fibrils. Alternate layers spiral in opposite senses. This arrangement, giving a laminate structure similar to that of plywood, is very strong and dimensionally stable. Since a cellulose fibril can only swell laterally the opposing spiral layers restrain one another. The next layer, S_2, which contains the major part of the fiber bulk consists of layers of fibrils all spiralling the same way. These layers, if freed from the constraining action of the two outer walls, can swell readily in aqueous suspensions.

Figure 2 shows a cross section of sprucewood in which the different size and wall thickness of the summer and spring grown fibers is evident. The spring fibers have a large cross section but thin walls, the summer fibers are thick walled. Surrounding each fiber in the wood and cementing it to its neighbor is the nonfibrous middle lamella. This is a complex chemical mixture, the chief component of which is lignin. The objective of all pulping processes is to dissolve away this layer selectively. Unfortunately none do so, without also removing some of the constituents from within the fiber itself. These are mostly the hemicelluloses, shorter chain hexosans and pentosans, which are embedded among the cellulose chains. We know very little of the way these components are distributed in the original fiber or of their distribution after pulping. The most probable explanation for some of the appreciable differences which exist between fibers from the same tree pulped in one case, for example, by the sulfite and in the other

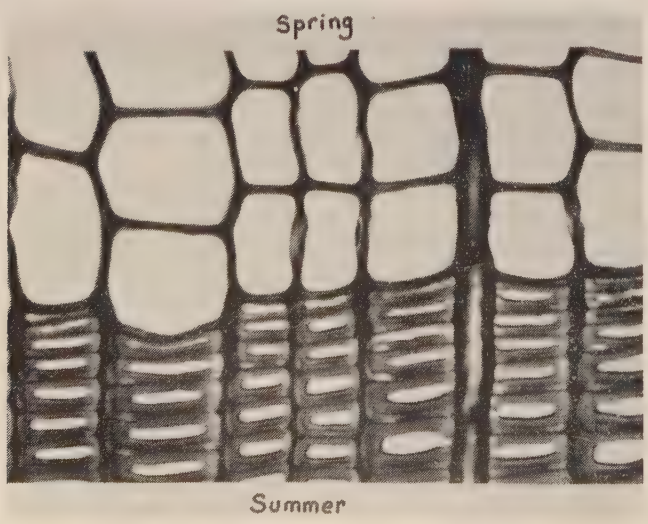

Fig. 2. Cross section of spruce wood

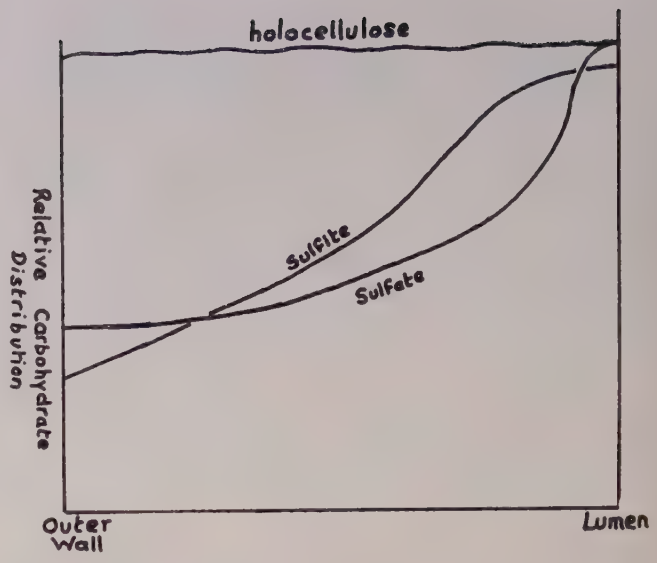

Fig. 3. Relative material distribution curves for: (a) spruce holocellulose, (b) spruce sulfite fiber, and (c) spruce sulfate fiber

—After Lange (3)

by the sulfate process is not the different amounts of hemicellulose extracted by one or the other process but the distribution of those remaining. Chemical analysis of the whole fiber only tells us part of the story. Techniques are required to determine the amount and distribution of the various hemicelluloses throughout the cell wall. Lange (*3*, *4*) has used both micro x-ray and microultraviolet techniques to determine the density distribution of all carbohydrates across the fiber wall (see Fig. 3). By following changes in this distribution throughout pulping and bleaching and by combining it with a knowledge of the amounts of the different hemicellulose removed at each step of the process it might eventually be possible to deduce the original sites of the different components.

Lange's technique has allowed us to deduce that:

1. The carbohydrate density distribution is very uniform across the fiber in its original state (i.e., as holocellulose).
2. Cellulose is very densely packed around the lumen, decreasing from almost 80 to 90% close to the lumen down to about 50% at the outer wall.
3. The remainder is hemicellulose, which is concentrated therefore toward the outside of the fiber. Removal of much of this material during pulping leaves the outer part of the fiber very porous whereas the core remains very dense.

A technique which would allow us to identify the different components *in situ* in the fiber would be of great value. One approach being studied (*5*), is to break up the fiber mechanically to separate the fragments from different portions and then to use chromatographic and spectrophotometric microanalyses. This is very tedious and the classification of the fragments presents some experimental problems. Fortunately, a Victoria Blue staining technique developed by Bucher (*6*) allows us to check the origin of the segments with a fair degree of reliability (Fig. 4). The degree of swelling is an important factor in determining fiber behavior. The swelling serves to open up the inside surfaces of the fiber, exposing new fibrils or hemicelluloses; it increases the flexibility of the fiber which allows fibers to approach one another more closely in a web and so increase the likelihood of bonding; it increases the mobility of the

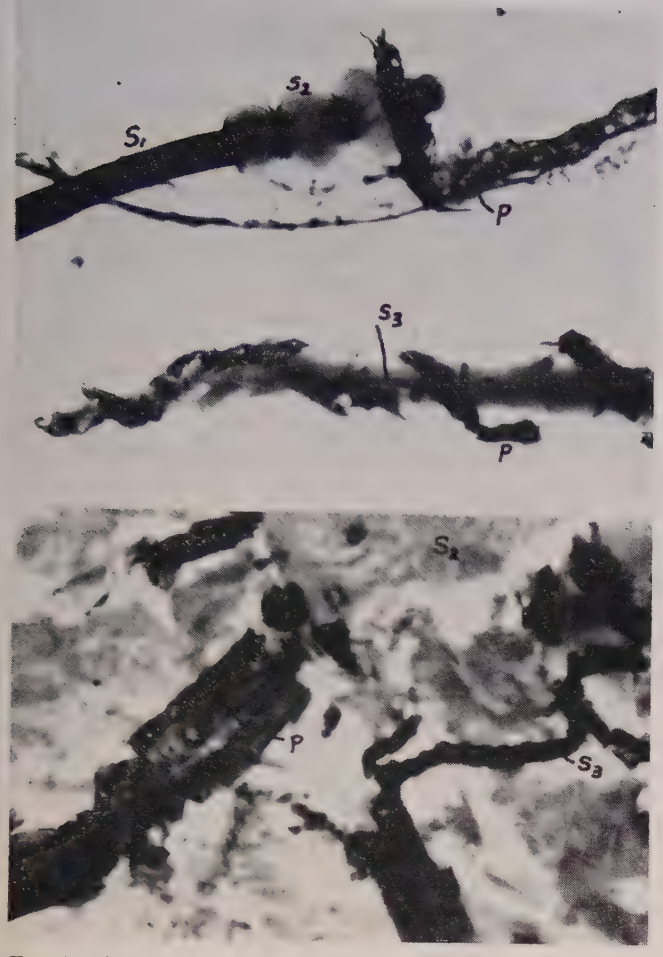

Fig. 4. Southern pine tracheid stained with Victoria Blue to show differentiation of cell walls. a, b, c are successive stages in swelling of fiber with cupriethylene diamine
—McIntosh (7

potential bond forming sites on the exposed surfaces so that they can move into orientations favorable for forming bonds with similar chains on another surface. The number of liquids capable of swelling celluloses are few and of these water or aqueous solutions have by far the most dramatic effects.

It is generally considered that the bonds which form between fiber surfaces are hydrogen or similar short range Van der Waal's forces. The surfaces are brought sufficiently close together for these bonds to form during drying by the extremely powerful surface tension forces which are set up as water is removed from the web. The hemicelluloses play a special role in promoting fiber bonding. Being short chain they are fairly mobile on a swollen fiber surface, more so than the longer cellulose chains. They can be thought to act as flexible links between otherwise unfavorably orientated cellulose chains. It is possible in this way to explain the reported correlations which exist between strength and hemicellulose content and yet to understand the not infrequent contradictions which are also reported. The hemicellulose must be present at the bonding surfaces to be of value. Also, as in the case of glue, an excess of adhesive is no further advantage and because of its short chain length may actually weaken the joint.

Beating or refining is the mechanical process by which the fiber structure is opened up to improve the strength developing potential of the fibers. Several effects of this process are readily observed under the microscope. The outer walls of the fiber are progressively removed or torn open creating fibril debris, and "fibrillation" of the fiber. The S_2 layer is exposed and permitted to swell. The surface area and so the area available for bond formation is increased. The fiber becomes more flexible. Inner surfaces are exposed and, in general, they will be richer in hemicelluloses than the outer walls which have suffered most loss from the pulping and bleaching chemicals. All these effects are favorable to bonding and bond strength. On the debit side the overall fiber strength is eventually reduced, many fibers are cut and so as beating proceeds most strength properties increase initially to a maximum value and then decrease. Tear strength which depends more on fiber length and fiber strength than bond strength decreases from the start.

Interfiber friction and entanglement undoubtedly make a major contribution to fiber web strength, especially in the wet web state. Some workers (*8*) believe that the increase of strength which occurs on beating is a direct result of the formation of additional fibrils which enhance interfiber entanglement and friction. The two concepts of swelling (and the ideas associated with it) and of fibril entanglement have been colorfully labeled the "boiled macaroni theory" and the "fuzzy fibrillar theory," respectively. Many workers consider the two concepts complementary and not mutually exclusive theories.

In addition to the chemical effects produced by the pulping and bleaching processes they also affect the physical condition of the primary wall. Giertz (*9*), using the Victoria Blue staining technique, has shown the varying degree to which the primary wall may be removed by different pulping and bleaching methods. These observations (see Table I) suggest the reason why a bleached pulp may develop strength at a faster initial rate than an unbleached fiber although its ultimate strength, because of loss of fiber strength and hemicelluloses, will be less.

Table I. (Giertz (9))

	Percentage primary wall removed
Unbleached pulps	
Strong sulfite	0
Medium sulfite	14
Rayon grade sulfite	68
Strong kraft	0
Soft kraft	0
Bleached pulps	
1. Unbleached sulfite	14
Bleached, Cl_2,-alkali-hypo-alkali-hypo	72
2. Unbleached kraft	0
Bleached, Cl_2-alkali-hypo-alkali-hypo	77
Bleached, Cl_2-alkali-ClO_2-alkali-ClO_2	41

In the light of the above discussion how then can we readily characterize a pulp, in terms of its fiber properties alone, so that we may predict the flow behavior of the pulp slurry, the de-watering characteristics of the forming web and the strength properties of the wet and the dry paper webs? Measurements of the physical dimensions of the fibers are useful. As the pulp is refined it becomes increasingly difficult however to decide how to measure the fragments and the fibrillation. Measurement of surface area is difficult at all times by direct methods and the various indirect ones undoubtedly measure different surfaces. In the pulp stage an aqueous method is desirable so that the fiber is measured in its swollen state. Silvering and dye absorbtion methods have been used but are difficult to reproduce and

their results are questionable for refined pulps (*10*). Permeability methods, either on preformed pads (*11*) or during a filtration experiment (*12*) are generally considered more reliable in spite of the care required and the approximate nature of the mathematical analysis used. This will be discussed again later. (Gaseous absorption may be used on dry paper but is not well suited to moist pulp.) Flexibility and strength factors for individual fibers can be defined and measured, usually by tedious techniques, but many determinations are required because of the wide statistical variations which occur. The bond strength per unit area is another factor which might be determined but it is a difficult measurement to make. Methods of doing this have recently been proposed by Page (*13*) and by McIntosh (*7*).

Further progress in our ability to predict the papermaking properties of fibers will be made as these and other techniques of measurement are developed and refined. Two excellent surveys of the present state of knowledge in this field of fiber properties appear in The Fundamentals of Papermaking Fibers—Proceedings of the 1957 Cambridge Conference (*2*), and in Emerton's "Fundamentals of the Beating Process" (*1*).

THE FLOW OF FIBROUS SUSPENSIONS

Fibers suspended in water modify the flow properties of the water to a marked degree. The extent of this modification depends on many factors, of which fiber length, fiber flexibility, and fiber concentration are the most important. The presence of fibers in a moving liquid provide additional means of transferring momentum within the liquid. This shows up as an apparent change in the viscosity of the fluid, as it is normally determined. Unfortunately for analytical convenience, this apparent viscosity varies according to the apparatus and shear conditions used to determine it, and early workers in this subject have devoted much effort to interpreting this anomalous data in terms of a variety of non-Newtonian liquid models. The consensus of recent work (*14–18*) is that a more profitable approach is to regard the system, not as a special type of liquid, but as a two-phase system, consisting of water with its usual Newtonian properties and of a multibodied solid phase, the fibers, dispersed throughout the liquid. In the development of this approach use has been made of several visual observations concerning the flow behavior. Most of this work has been concerned with flow in circular pipes. Such a system has several advantages. It is axisymmetrical and therefore readily amenable to analysis, it avoids the confusing presence of secondary flows which occur in rectangular channels and it also permits comparison with the large body of experimental results available for water flow in circular pipes. It is also a very common way of moving pulp suspensions around.

The most significant feature of a flowing suspension is the existence of a peripheral annulus of water which contains little or no fibers and in which most of the shear strain occurs. This annulus is a dynamic phenomenon and does not exist when the suspension is at rest. A flow model characterized by a peripheral annulus has been found to be consistent with the experimental friction data and to provide a satisfactory basis by which to correlate these data for a wide variety of pulps and flow conditions. The inability of any of the non-Newtonian models to predict this characteristic lack of macroscopic homogeneity is a major reason for their rejection in this problem. Daily and Bugliarello (*15*) have demonstrated other analytical reasons why none of the usual non-Newtonian rheological models are able to correlate the experimental data satisfactorily.

The flow of water is characterized by a laminar flow regime at low rates, with a parabolic velocity distribution; a transition point defined with-in narrow limits for all sizes of pipe by a critical Reynolds number; and a turbulent flow regime with a flatter velocity profile, which becomes more so as the flow rate is in-

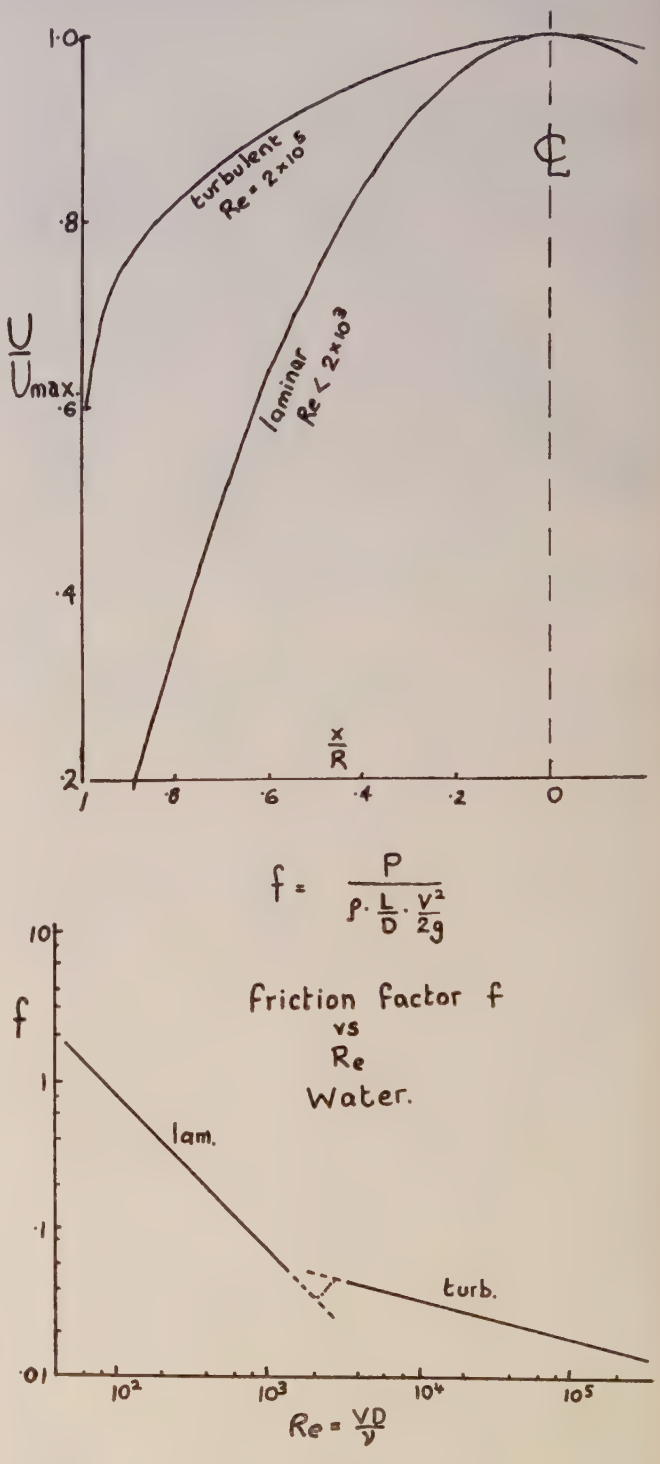

Fig. 5. (a) Velocity distributions in water. (b) friction factor plot for water

creased. Friction factor plots reflect these changes in the shear rate at the pipe wall (Fig. 5).

In contrast the flow of pulp suspensions at low rates consists of a laminar regime in which all the velocity gradient occurs in a peripheral layer which grows in thickness as the rate increases. The fibers move along inside this layer without relative motion to one another, i.e., as a plug. As the flow rate increases a point is reached at which turbulence begins to occur in the annulus adjacent to the plug surface. This point is characterized by a Reynolds number based on the water annulus dimension and also on a critical shear rate at the boundary of the plug, which is a property of the fibers. With further increase the turbulent zone encroaches on the plug forming a zone in which fibers and water are in turbulent motion. This transition regime ends when the plug is entirely eroded away, and a fully turbulent regime exists. The velocity profiles in the turbulent regime are much flatter in the center than for water, especially at the higher consistencies, and less steep at the boundary although they gradually tend toward the water profiles as the flow rate is increased further (Fig. 6). There is evidence to suggest that

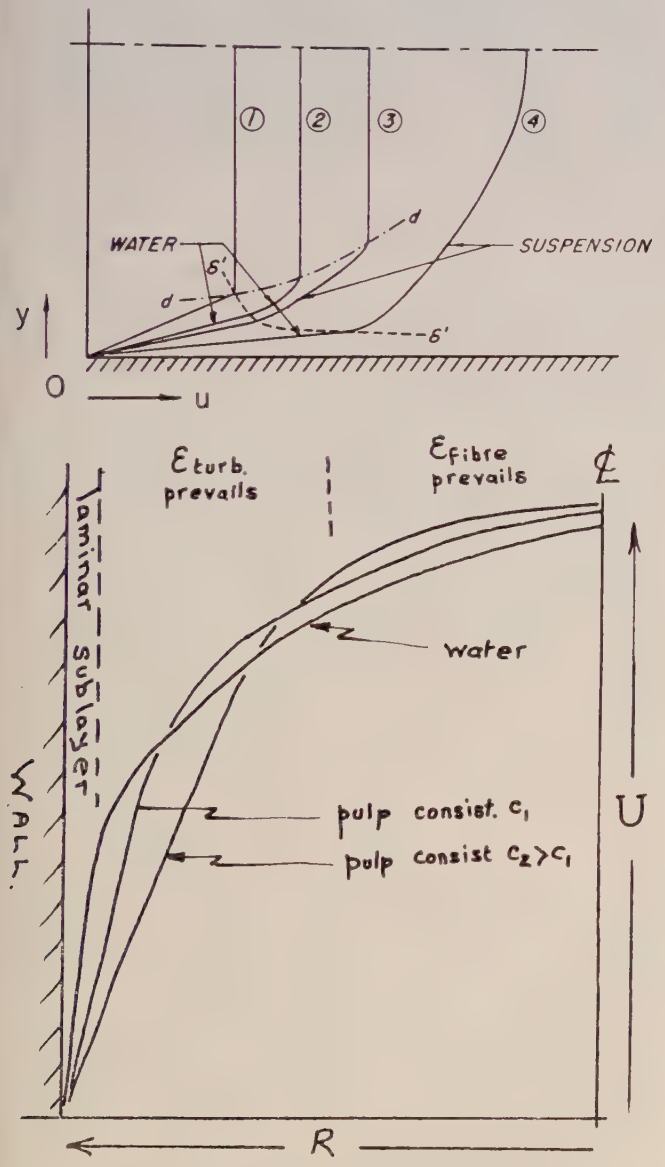

Fig. 6. Velocity distributions for stock compared to water (a) plug flow (1) and transition flow (2), (3), and (4) and (b) turbulent flow

even in the fully turbulent regime the fibers close to the axis are continuously forming and reforming networks of limited dimensions. These observations are also in accord with the fraction factor plots of which Fig. 7 is typical.

A fiber, because of its finite length, extends through parts of the liquid which in the absence of fiber would have different velocities. The fiber can only move at one velocity and therefore a shear field acting on the fiber is established. Jeffrey (*19*) considering idealized oblate spheroids in shear fields predicted that they would precess as a result of the shear. Mason and co-workers (*20*) have shown that this analysis is correct for rigid rods, bubble doublets, and idealized fibers. Their results with flexible fibers have extended this analysis, showing that flexibility and hingepoints on a fiber lead to complicated snakelike rotations.

These rotations have the effect of increasing the effective volume of the fiber since it is able, as a result of this motion, to react with other fibers whose sphere of motion intersect its own. It is possible to calculate a specific concentration of particles at which the effective volumes of all the particles add up to the volume of the liquid. The value of this concentration depends very largely on fiber length, but for typical papermaking fibers is between 0.05 to 0.2%. Beyond this consistency frequent fiber interaction occurs and this leads to flocculation, and to the formation of a continuous but dynamic network of fibers extending through the liquid. The formation of such a network may be demonstrated in a variety of ways. Mason, *et al.* (*17*), have measured network tensile strengths at concentrations as low as 0.3%. Daily (*15*) found that suspensions above 0.2% after stirring in a beaker in one direction gradually returned to rest and then began to rotate in the opposite direction for a short while. This counter-rotation effect is explained by the elasticity of the network, and does not occur at concentrations below about 0.2%.

In addition to its ability to transmit momentum across the liquid shear field the fibers also act to dampen out turbulent motion in the liquid. They not only decrease the overall intensity but they also strongly attenuate the higher frequencies. Figure 8 compares the energy spectrums of water and suspension at equal Reynolds numbers. Increasing consistency, fiber flexibility, and fiber length all increase the network strength and thereby its modifying action on the flow. Daily, *et al.* (*15*), have differentiated between momentum transfer through the turbulent motion of the liquid and through the network and have shown how the transfer coefficients for each process may be determined. Their results (see Fig. 9) show that transfer by the network is most important at the center of the pipe and by the liquid toward the walls.

Both Mason and Daily have suggested that this network type of flow is not peculiar to pulp suspensions and have cited the flow of clay slurries, greases, and some polymer solutions (*17*, *15*), as other probable examples.

Chemical additives, notably gums, such as locust bean gum (LBG), can have a marked effect on these network properties. Mason (*17*) has reported that 2% LBG will reduce network tensile strength by 50%.

Finally I would like to refer to some recent work by a

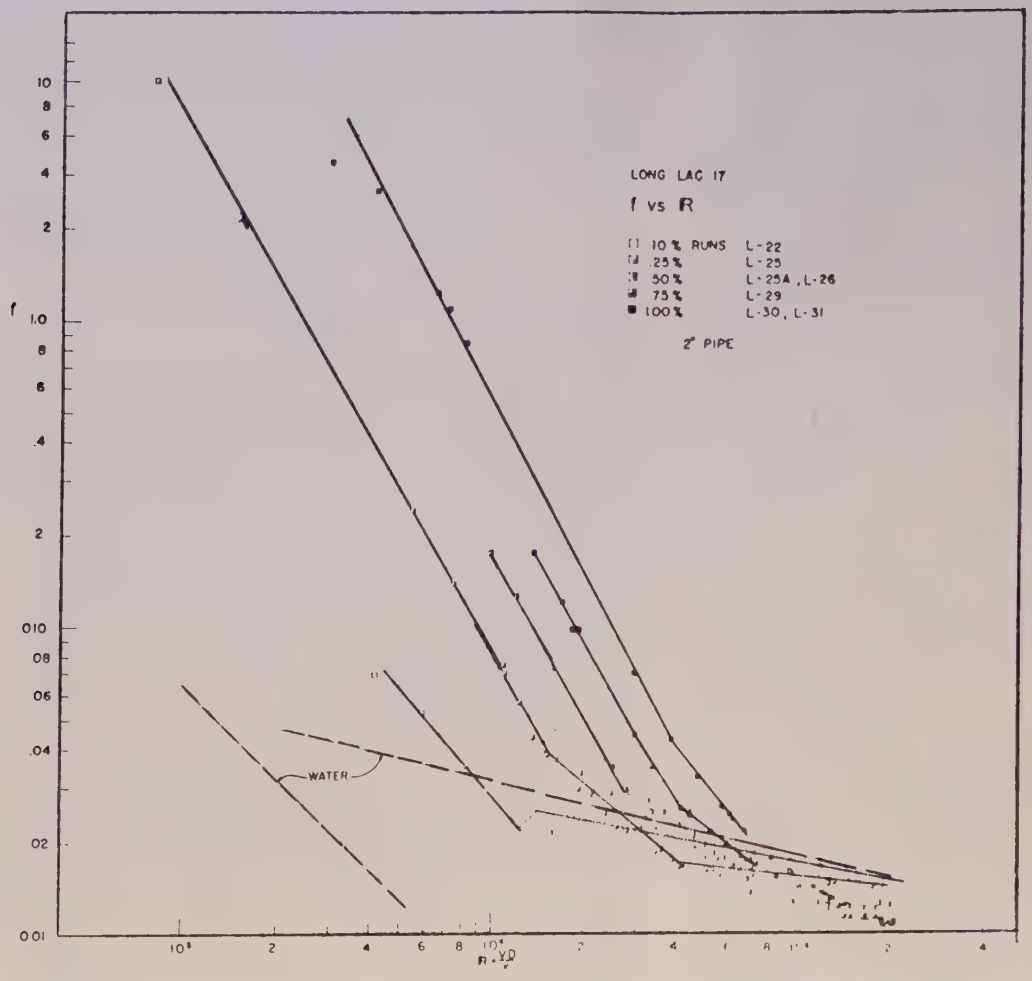

Fig. 7. Friction factor plots of pulp

colleague, Long (*21*), who has been studying the orientation and flocculation tendencies of fiber suspensions in a variety of slices. This work has involved the development of very high-speed microphotographic technique to observe and to measure the individual fiber behavior under these conditions of transient acceleration. Figure 10 shows a typical photograph in which the slurry was moving at 1500 f.p.m. The behavior of the fibers in these experiments was consistent with the ideas developed above. Below 0.2% the fibers respond rapidly to the accelerating field and there is a considerable alignment of the fibers toward the flow direction. As the consistency increases the network progressively retards alignment and the duration of the acceleration, as determined by the geometry of the slice, is increasingly important. At higher consistencies, and with a very rapid acceleration there is a suggestion that network rupture may occur, leading to the formation of large scale flocs. Under more gradual acceleration the network is able to continuously reorganize and avoid such definite failures. For a more detailed study of the flow of fibrous suspensions reference is made to Daily, *et al.* (*15, 16*), and to Mason, *et al.* (*17*).

FLOW INSTABILITIES

The uniformity of the paper web is determined by

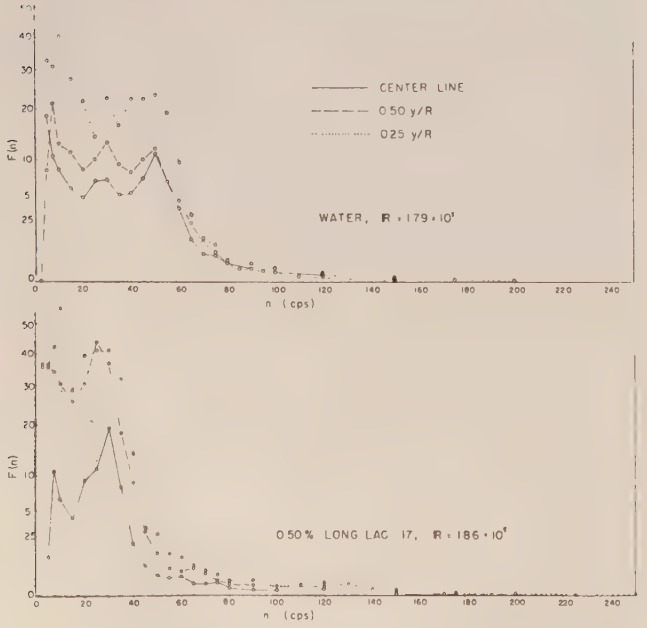

Fig. 8. Energy spectrums of water and pulp at equal Reynold numbers (15)

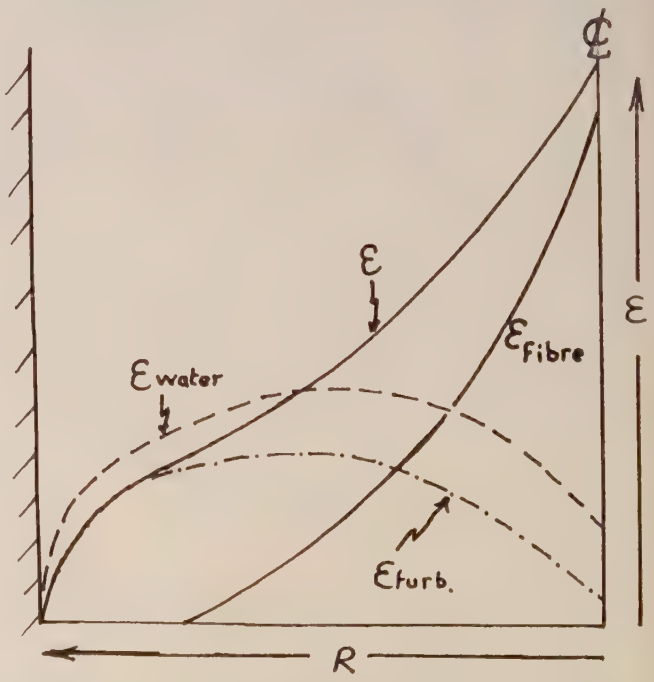

Fig. 9. Momentum transfer coefficients in pulp suspension pipe flow (15)

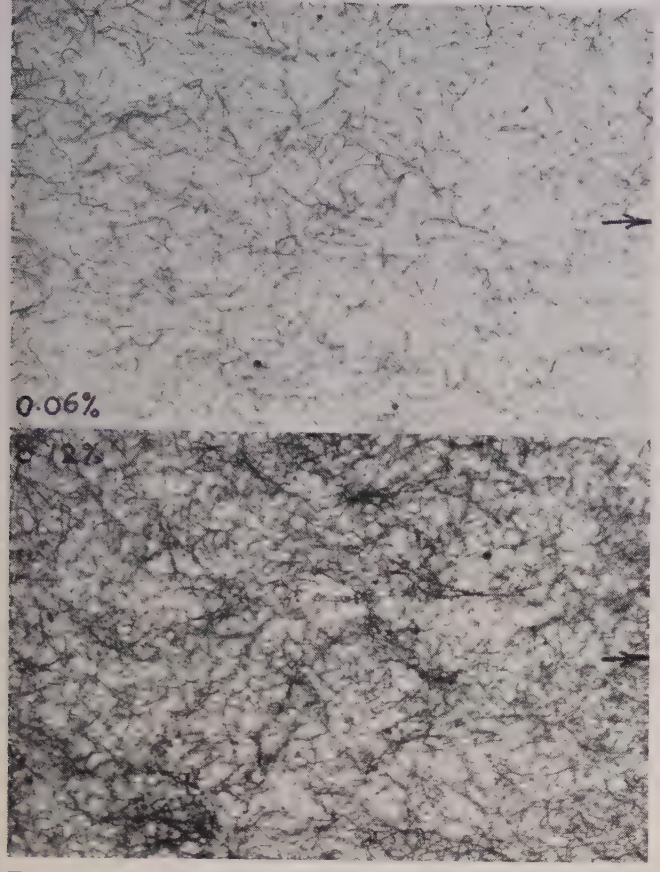

Fig. 10. Very high speed (0.8 micro sec.) microphotograph of fiber orientation in a paper machine slice flow at 1500 f.p.m. (21)

three factors, namely, the uniformity of the slurry concentration, the uniformity with which the slurry is metered onto the forming screen or "wire" by the headbox and lastly by the extent to which the machine retains this distribution during the forming period. I do not propose to discuss the problems associated with uniform mixing, and blending of fiber mixtures etc., nor with the wide range of commercial equipment available for metering the slurry onto the wire. Scientific methods are being used increasingly in their study and design but these fall outside the scope of this paper. There are indications however that as our basic knowledge is increased by such studies as the ones I am describing it will be possible to rely less on papermaking lore and more on scientific laws in our design work.

In addition to the nonuniformities of distribution which can be attributed to large scale intermittent vortices or to the irregular shedding of eddies within the slurry distribution system evidence has been gradually accumulated over the past few years which suggests the widespread occurrence of variations which have a regular frequency or spacing across the paper sheet. Thus far all appear to be formed by one or another of a class of hydrodynamic instabilities first analyzed by Taylor (*22*) who studied the stability of laminar flow between the concentric cylinders of a Couette viscometer. He predicted and found that under certain conditions the laminar flow becomes unstable and changes to a vortex type of flow, consisting of pairs of opposed vortex rings arranged around the inner cylinder. These are usually referred to as Taylor vortices. Others have extended this analysis to explain similar instabilities in the flow of liquids over concave surfaces. The name of Gortler is strongly identified with this work, and the instabilities are called Taylor-Gortler vortices. More recently Taylor (*23*) has considered the stability of accelerated liquid boundaries in which the acceleration is unidirectional and not centrifugal in origin as in the case of the Taylor-Gortler vortices. Again regularly spaced disturbances occur and the phenomenon is now referred to as Taylor instability of an accelerated boundary. It is of interest in many applications, including among other things, the surface profile stability of nose cones when subjected to the very high frictional heating on re-entering the earth's atmosphere. Instances of all three types of nonuniformity have been studied in relation to papermaking applications and in at least three cases significant contributions to the general hydrodynamic theory of the subject have been made by workers studying problems arising in papermaking systems.

An early recognition of this type of instability in headbox flow was by Lee (*24*) who showed that a regular pattern of weight variation across the machine was due to Taylor vortices created by circulation of stock around a solid roll just ahead of the slice. Using a laboratory model of the system he studied the initiation of vortex flow for different roll speeds, annulus dimensions, and different roll smoothnesses. He used water, water-glycerine mixtures, and finally pulp suspensions to determine the effects of viscosity changes. His results showed a very pronounced vortex pattern as predicted by Taylor's stability criteria, that the intensity of the vortices increased with the roll speed and that the

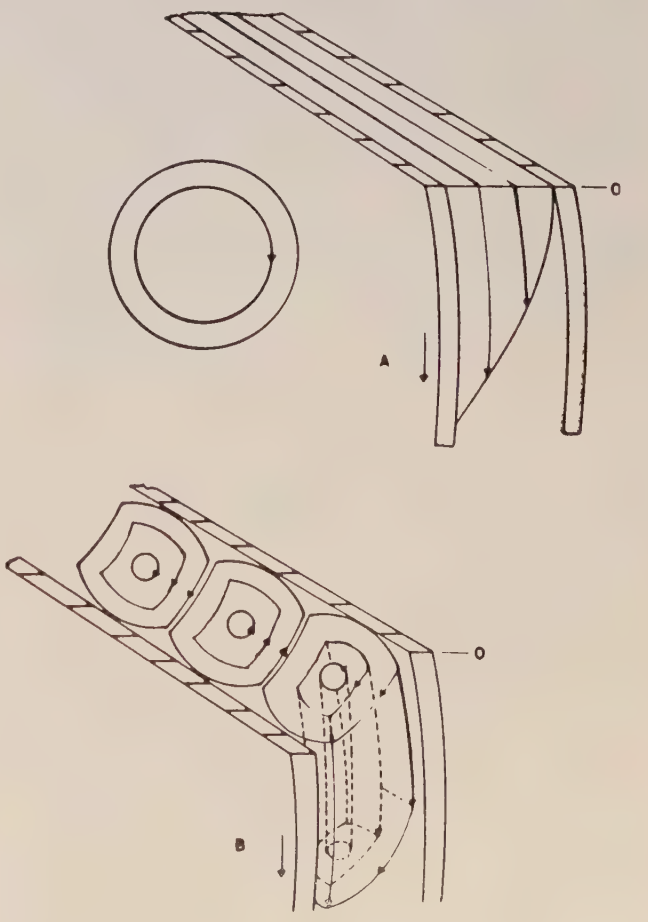

Fig. 11. Vortex pattern created by Taylor instability (27)

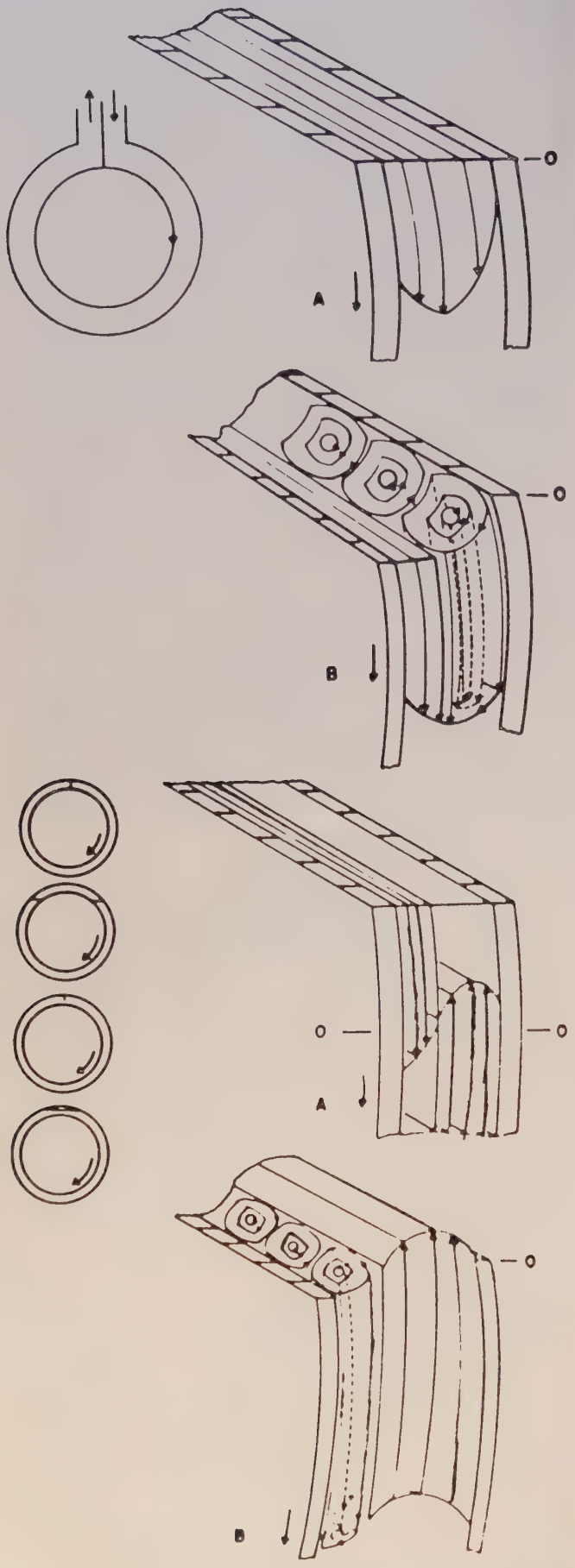

Fig. 12. Flow patterns and instability in a partially filled annulus (27)

(a) circulation due to pumping. (b) circulation due to reverse flow.

fibers delayed the inception of the vortex pattern. Lee was able as a result of this work to reduce the size and scale of the pattern to a point that it caused no weight variation. He also commented very briefly that vortices of the Taylor-Gortler type were possible in the flow around curved channels in the headbox (Fig. 11).

Appel (*25*) followed up Lee's work and studied the addition of an axial flow component, in addition to making a more detailed study of the vortex system itself. Appel found that the vortices were not symmetrical, that their intensity increased linearly with the speed of the inner roll up to a second transition point at which the vortices changed from laminar to turbulent ones. With further speed increases the vortex intensity increased, passed through a maximum and then decreased as the turbulence began to destroy the pattern. Axial flow was found to cause an axial movement of the vortex system and also to change the transition points between the different regimes.

Nissan and co-workers (*26*, *27*) have studied a variety of flows resulting from the combination of rotating cylinders and of flow over concave surfaces under a pressure gradient. A special case of this type of flow occurs when the space between a rotating inner roll and a stationary outer one is only partially filled with liquid. The circumferential flow may be caused by reverse flow or by pumping. These cases are illustrated in Fig. 12. In such a case vortex motion will occur above a certain critical speed but will only occupy a portion of the annulus, outside of which the flow will remain stable. Nissan's work has defined criteria by which any combination of flow type can be analyzed for likely instability, and by which its geometry and critical speed can be predicted.

This analysis is directly applicable to cylinder paper machines and also to rotary filters, in which the inner rotating cylinder is the forming cylinder and the outer stationary one the vat circle. These practical cases have the added complication of a radial flow component due to drainage into the cylinder. The influence of this additional feature remains to be analyzed. Another example is a size or coating applicator roll running partially submerged in a pan.

A flow instability of a more complex nature is encountered over the early part of the table roll section of the paper machine (Fig. 13). Three distinct problems have been identified. The suction created by the drainage action of the table roll causes the forming wire to wrap the roll for a short distance after the top of the roll. Thus the stock passing over the roll suffers first a convex deflection followed by a concave one. See

Fig. 13. Photograph showing instability on a fourdrinier wire

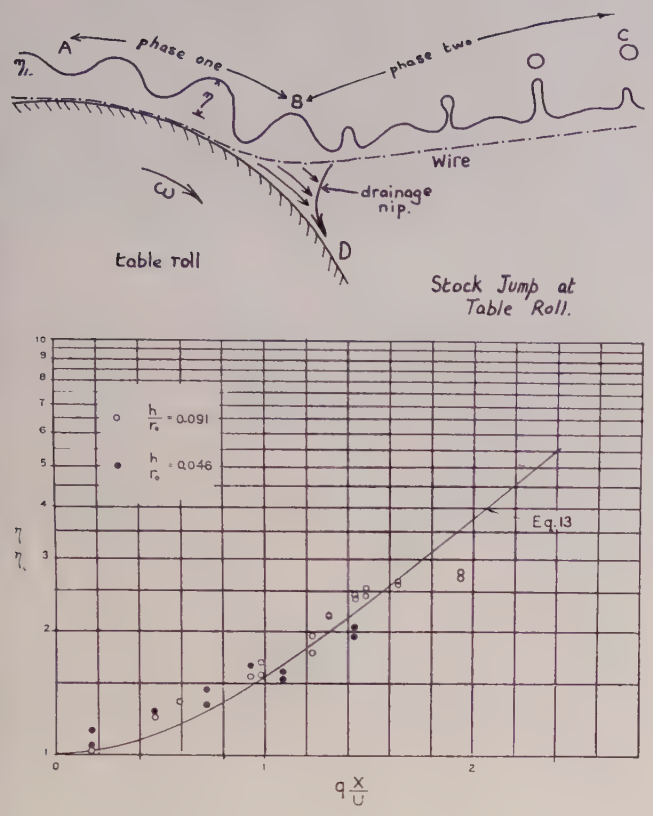

Fig. 14

(a) Enlarged section at a table roll. (b) Growth of disturbances over the table roll (*29*).

Fig. 14 which is a magnified section at the roll. Burkhard and Wrist describing this flow instability qualitatively (*28*) suggested that the mechanism for the rapid growth of the instability as the stock passed over the roll was the same as that studied by Taylor (*23*). Yih and Spengos (*29*) have extended Taylor's two dimensional analysis to cover disturbances in three dimensions, and have applied the results to the situation over a table roll. They obtained confirmation of the predictions using a laboratory model. The instability which occurs immediately following this downward acceleration is regarded by Yih as a separate phenomenon and one so far resisting a strictly analytical solution. His approach has been to collect experimental data and to handle it with dimensional analysis techniques, see Fig. 15. Mardon and co-workers (*30*) have examined the same problem. They have used analyses of high-speed cine films and a more simplified analysis than that developed by Yih. Their conclusions however are in broad agreement.

The third instability problem is encountered on the surface of the table rolls themselves, beneath the wire. Here instability of the film of draining water carried on the roll surface is caused by centripetal action. This is a special case of Couette flow in which the outer surface is a free liquid surface. Yih (*31*) has analyzed this case and predicted the spacing of the circumferential ridges which are formed. His theory is in good agreement with practice. This particular problem has application also to the films of size or of coating color on the face of coating presses. It explains for example the probable cause of "turkey tracks" in roll coated sheets. Its results may also be applied to printing press inking fountains, oil films on rotating shafts, ribbing patterns on tin plate, etc.

THEORIES OF FORMATION AND OF DRAINAGE

Papermaking is a filtration operation of a rather unusual type. Filtration efficiency and rate take second place to the physical condition of the filter mat. In this respect it differs perhaps from similar operations in other manufacturing industries in which the filter mat or cake is often disintegrated after removal from the filter screen or washer cylinder. However filtration rates and efficiency do have an important bearing on the economics of the process consistent with the maintenance of the desired sheet quality. For this reason the interrelation of pulp properties, drainage driving forces, and the mechanics of the filtration process has been studied by many workers. In addition to the final papermaking process itself allied situations occur many times during the overall process. Pulp washing in pulp mill and bleach-plant, pulp thickening in the groundwood mill, and finally fiber and mineral recovery from the process effluent, are all filtration operations, of the more conventional type.

Five conditions differentiate the particular problems faced in formulating a filtration or formation theory for pulp fibers.

1. Pulp fibers are highly compressible and their filtration resistance changes appreciably according to the applied pressure.
2. Pulp mats are very plastic and exhibit both hysteresis and nonrecovery if the pressure is cycled.
3. The retention efficiency of the process is usually quite low initially and increases during the process.
4. On the fourdrinier papermachine, in particular, the applied suction forces are dynamically produced, intermittent in nature, and variable in magnitude during the suction pulse.
5. Slurry consistencies are very low, porosities tend to be very high and final mat thicknesses are usually very small so that experimental determinations of such things as porosity distribution, pressure distribution, etc., are difficult to determine for use as guides to theoretical analyses of the process.

During the 1930's several workers contributed to the mathematical analysis of filtration theory. Their derivations were based on the use of D'Arcy's law and the concept of a specific resistance in the case of noncompressible beds and to an average specific resistance which is a function of the filtration pressure in the case of compressible solids. A review of this work is given in

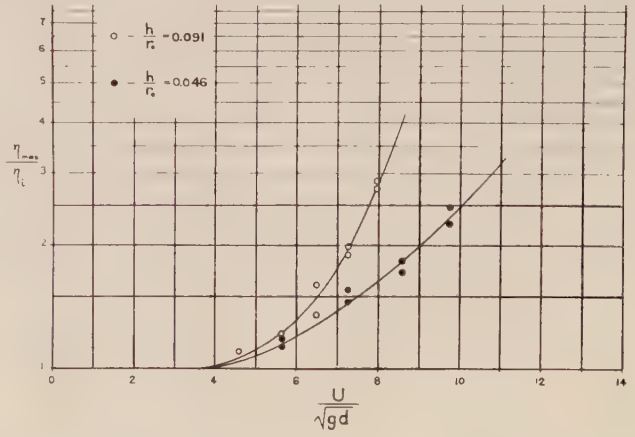

Fig. 15. Growth of disturbances downstream from the table roll (*29*)

several texts (*32, 33*). In the field of permeability of porous beds the most successful relationship between the physical properties of the bed and the permeability was that finally modified by Carman, the Kozeny-Carman equation, which related the permeability to the concentration, specific surface and specific volume of the solids particles. Later work (*34*) confirmed the equivalence of specific filtration resistance and specific permeation resistance, for incompressible materials. Early workers with paper fibers (*35, 36*) followed this general approach. In particular Mason and Robertson (*11*) developed the use of a permeometer cell and rectified form of the Kozeny-Carman equation

$$\left(\frac{Q\rho\nu}{A} \times \frac{L}{\Delta p} \times \frac{c^2}{c^2}\right)^{1/3} = (1 - vc)/(k\, S_w^2)^{1/3}$$

as a method for determining values of specific surface and volume. They assumed the "constant" k to be constant and equal to 5.55, the value determined by Fowler and Hertel (*37*) for a variety of fibrous materials.

Ingmanson, in a series of papers (*12, 38*), has started with the differential form of this equation and applied it to both constant pressure and constant rate filtration problems. In order to integrate his equations he made use of a compressibility relationship between consistency c, and applied pressure p, derived experimentally by Campbell (*39*),

$$c = mp^n$$

Ingmanson pointed out that $c = M_0 + mp^n$ was more appropriate at low pressures to avoid zero consistency at zero pressure. He also assumed that the flow rate is constant throughout the mat. He used his derived formulas for determining values of specific surface and volume from filtration experiments.

In the recent paper Ingmanson, *et al.* (*38*), introduced further refinements. They found that over the wide range of porosities encountered the "constant" k varied and was best represented as a function of porosity by the equation

$$k = a\,\frac{(1 - vc)^3}{(vc)^{1/3}}\,[1 + b(vc)^3]$$

where a and b are constants equal to 3.5 and 57, respectively. Using this additional relationship they showed good agreement between the calculated and the measured pressure distribution for water permeation through a thick mat previously deposited by filtration. They reported that in this new form the filtration equations could not be integrated analytically and used graphical methods of solution in their paper.

A more exact mathematical derivation has recently been made by Meyer (*40*). His derivation is based on the differential form of the Kozeny-Carman equation, the Ingmanson form of the "constant" k, the extended form of Campbell's compressibility relationship, and continuity equations for both water and fiber. A consequence of the continuity equations is that for compressible mats the flow rate is not constant through the mat but increases toward the wire. These equations reduce to a pair of simultaneous partial differential equations

$$\frac{ND^2}{\rho\nu}\, s^k \frac{\partial}{\partial\eta}\left[C^*(\gamma,s)\,(\gamma - 1)^r \frac{\partial\gamma}{\partial\eta}\right] + \eta\,\frac{\partial\gamma}{\partial\eta}\,\frac{(\delta^2)'}{2} - \left(\frac{\partial\gamma}{\partial t} + \frac{s'}{s}\,\gamma\right)\delta^2(t) = 0$$

$$\left[(\delta^2)' + \frac{2s'}{s}\,\delta^2\right]\int_0^1 (\gamma - 1)\,d\eta + 2\delta^2\int_0^1 \frac{\partial\gamma}{\partial t}\,d\eta = -2\,\frac{ND^2}{\rho\nu}\, s^{1+k}\, I_C\,(s,\Delta p)$$

Solution is not possible by analytical methods and numerical solutions are necessary. Digital computer solutions have been prepared for the special cases of

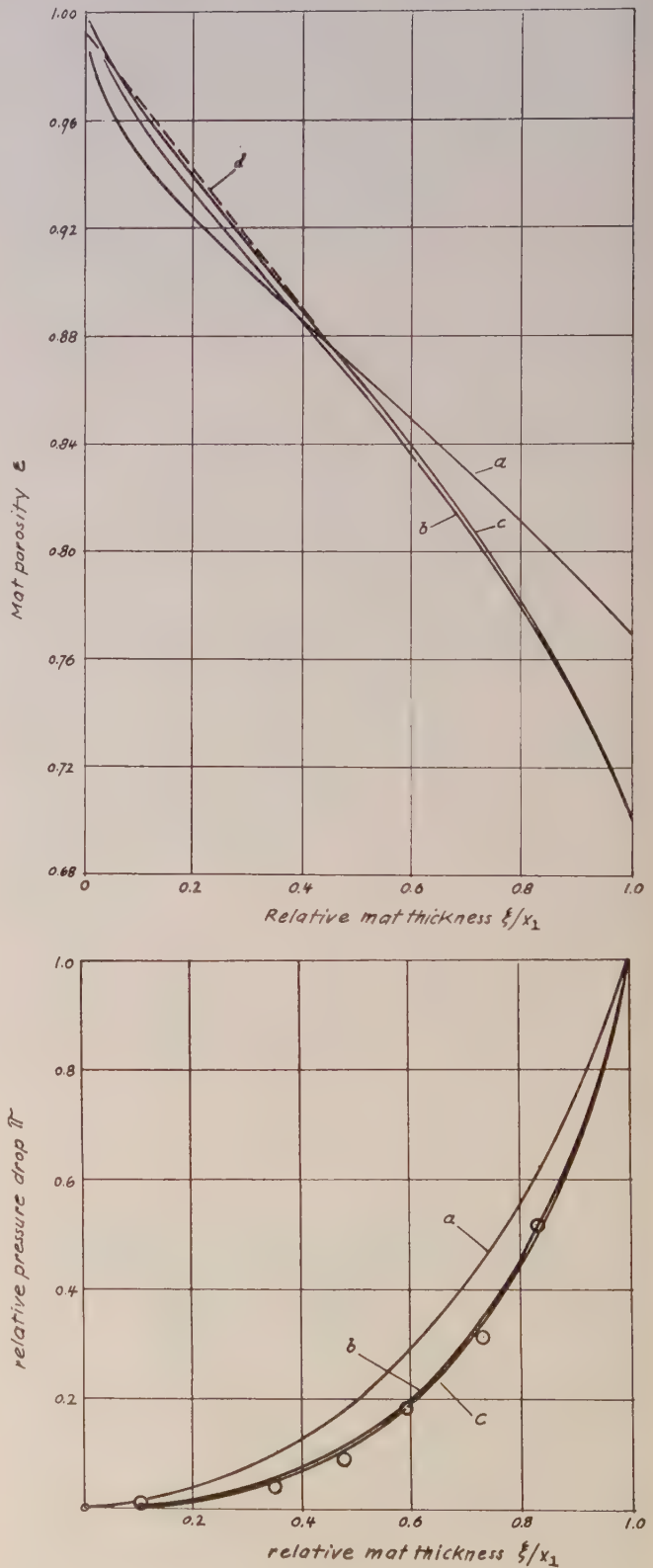

Fig. 16. Porosity and pressure drop relationship for constant pressure filtration

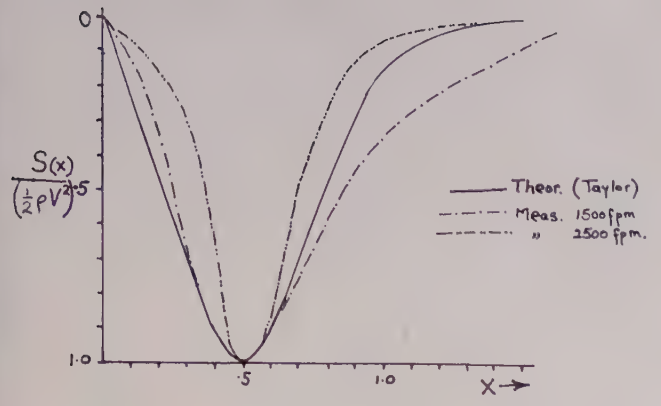

Fig. 17. Suction profile of table rolls (28)

constant pressure and of constant rate filtrations with retention varying according to a relationship derived empirically by Han (*41*)

$$s(t) = s_s - s_{w0}\, e^{(\beta Bt)}$$

Figure 16 shows the predicted trends of the porosity distribution and relative pressure drop for a constant pressure filtration for the three sets of data in Table II. An experimental check of the theory was provided in the case of Data III by Ingmanson (*38*), agreement was very good.

Table II

	Data I	*Data II*	*Data III*
c_1	0.006	0.001	0.0001 g. cm.$^{-3}$
v	2.12	2.12	2.12 cm.^{3} g.$^{-1}$
S_v	3070	3070	3070 cm.^{2} cm.$^{-3}$
m	0.01815	0.0269	0.0269 g.$^{1-n}$cm.$^{2n-3}$
n	0.376	0.376	0.376

Little progress has been made with a theory of fiber retention by wire screens. The process is a statistical one, and difficult to formulate. De Montigny (*42*) has studied retention of fibers on a widely spaced grid system and found fiber length a major factor. Kallmes and Corte (*43*) have studied the orientation and location of fibers randomly falling on a plane. In order to completely determine the filtration process it would be desirable to have more study of this phase.

Although these filtration theories are useful to provide a basis for the method of measuring specific surface and volume the major motivation for their development is the prediction of drainage rates on the paper machine, under different conditions of slurry consistency and pressure distribution than those typical of laboratory evaluations. In order to accomplish this it is first necessary to know what form the drainage pressures take. On a fourdrinier machine nearly all the filtration occurs as the wire passes over a series of table rolls. Originally intended merely as conveyers it has recently been demonstrated that they are the major cause of drainage and produce suction pulses proportional to the square of the machine speed (*28*). Theoretical and experimental determinations of the suction profiles have been found to agree very closely (Fig. 17). It is interesting to note that although the table rolls had previously been considered to produce a weak suction effect due to surface tension forces the presence of the very high vacuums was first predicted theoretically and only later found experimentally. We have already seen in the previous section how these high forces can create problems of instability over the rolls.

The free slurry disappears very early over the suction boxes and a new regime of water removal called "thickening" takes over. Here water is removed by compressing the mat and it terminates when air begins to enter the larger capillaries, at which point the problem becomes one of three-phase flow. Studies of these phases have been made by Hisey (*44*), Barkas, *et al.* (*45*), Parker (*46*), and by Robertson (*47*). Compression moduli, pore size distribution, and specific volume, as determined by the permeability method, are major factors in describing the physical relationships involved. However creep, and other irreversible rheological effects are known to occur and this phase of the process is still not well understood.

WET WEB RHEOLOGY

The compressibility of wet fiber mats was discussed in the preceding section with respect to the forming process, and to the following thickening phase. In these stages there is a considerable concentration or porosity gradient through the mat and compression is the result of fluid frictional drag. The succeeding operations in the papermaking process are concerned with the consolidation of the mat and the attainment of a fairly uniform density throughout its thickness. Dandy rolls, lump breaker rolls, and wet presses all act toward this end and in doing so remove additional water from the web. When pressure is applied to a mat in this condition it performs two functions, the removal of water against the flow resistance of the mat and the compression of the fibrous network. The relative importance of these two factors depends to a large extent on the time factor and to a lesser degree on the extent to which air has entered the mat. Initially, the degree of compression is controlled by the rate and ability of the water to leave the mat. With longer time it is controlled by the compression modulus of the fibrous mat. The stress distribution in a roll nip is complex and pressure gradients exist in two dimensions. It is understandable therefore that most progress has been made in the isolated study of one dimensional compression.

Campbell (*39*) was the first to observe the empirical relation between mean consistency and pressure to be of the form

$$c = mp^n$$

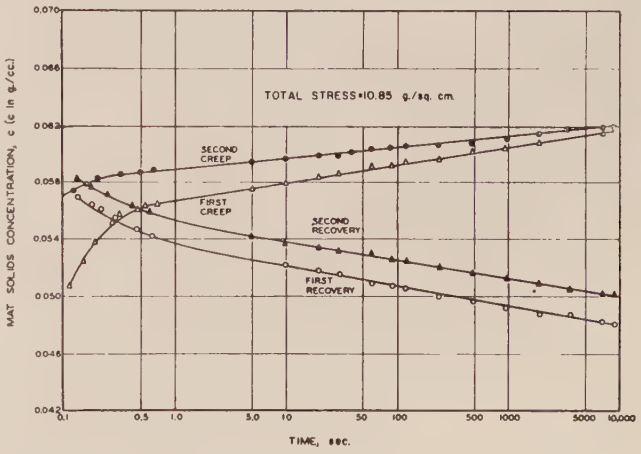

Fig. 18. Creep relationships for pulp mats on pressure cycling (48)

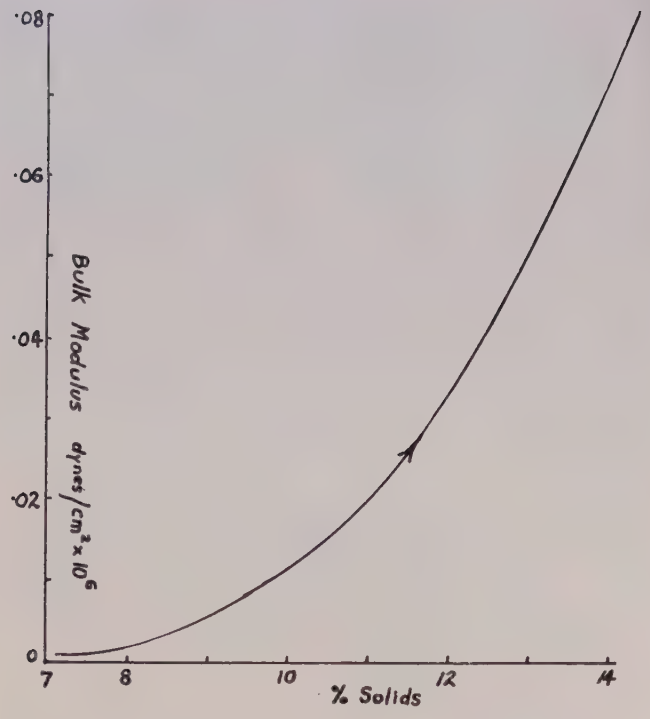

Fig. 19. Bulk modulus of a pulp mat as a function of consistency

It has long been realized that pulp mats creep under sustained pressure and in determining Campbell's equation experimentally it is necessary to define the time after application of the pressure at which the compression measurement shall be made. Ingmanson has pointed out the need to add a small but finite constant to the equation to satisfy the finite consistency at zero pressure. Wilder (*48*) studied the creep and creep recovery behavior of a fibrous mat over long periods and for successive cycles. He found that, except for extremely short intervals of time during which filtration resistance was controlling, the relationship was of the form

$$c = c_0 + (m_0 + m\log t)p^n$$

For the first few cycles the constant coefficients of the equation change for each compression and relaxation phase. After about 5 or 6 cycles the mat becomes conditioned and the constants approach steady values, one set for compression and another for recovery (Fig. 18). Wilder observed and was able to explain deviations from this relation at times up to about 5 sec. in terms of the known permeability of the mat and the frictional drag of the water being expelled by compression.

Barkas, *et al.* (*45*), discussed the elastic properties of a wet web assuming it to be made up of fibers all parallel to the plane of the web, and that the behavior of the fiber in the web was identical with that of an isolated fiber. Using hydrostatic tensions to produce compression he measured the bulk modulus as a function of moisture content. His results are presented graphically in Fig. 19 and show that bulk modulus increases as the moisture content is reduced. He also pointed out the hysteresis effect and the way the bulk modulus against moisture content relationship changed during cycling until it eventually reached two reproducible curves, one for relaxation and one for compression.

Kurath (*49*) has studied the shear modulus of a pulp

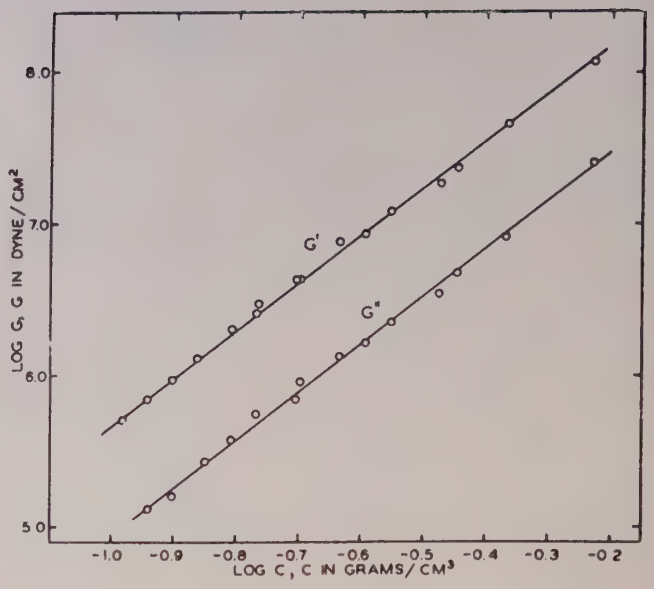

Fig. 20. Shear modulus as a function of consistency

mat under the dynamic condition of a shear strain varying sinusoidally for a number of different frequencies in the range 6 to 1000 cycles per sec. He found the shear modulus was a complex quantity, frequency dependent, and also a function of mat consistency. His results were best correlated by the relationship:

$$c = m^*G^{*n}$$

where n was found to be numerically equal to the n in the compression equation of Campbell. The existence of a component of stress out of phase with the strain suggests a viscosity effect. Kurath showed that this viscous term is not due to the flow of the water backwards and forwards through the mat, and concluded it was due to "cellulose chain motion, i.e., flow in the fiber walls themselves at the points of interfiber contact."

Noting the similar dependence upon consistency of the modulus in his derived equation and that of pressure in Campbell's, Kurath showed that both might be correlated by means of a function Q, such that

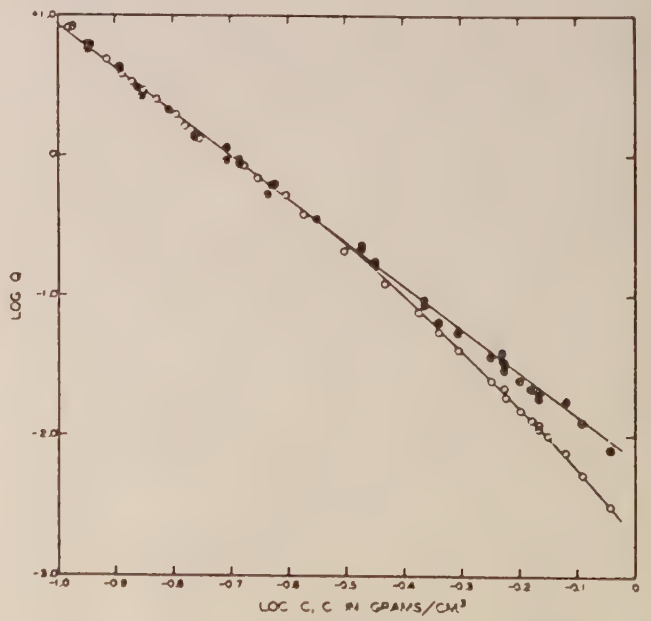

Fig. 21. Kurath's Q function as a function of consistency (49)

$Q(f,g)\ p = p_0$

$Q(f,g)\ G^*(jw) = G_0^*(jw)$

where p_0,$Go(jw)$ are the normal stress and complex shear modulus respectively at an arbitrary reference pad consistency. He suggested Q was determined by the number of fiber-fiber contacts in the web and by the magnitude of the normal force exerted at these points of contacts. Values of Q derived from experimental data for both shear and compression were shown to be in close numerical agreement over a wide range of consistency (Fig. 21).

Another rheological property of fiber mats that has been studied experimentally is the response to linear stress. This property is of very great importance practically since the wet web must support itself under ten-

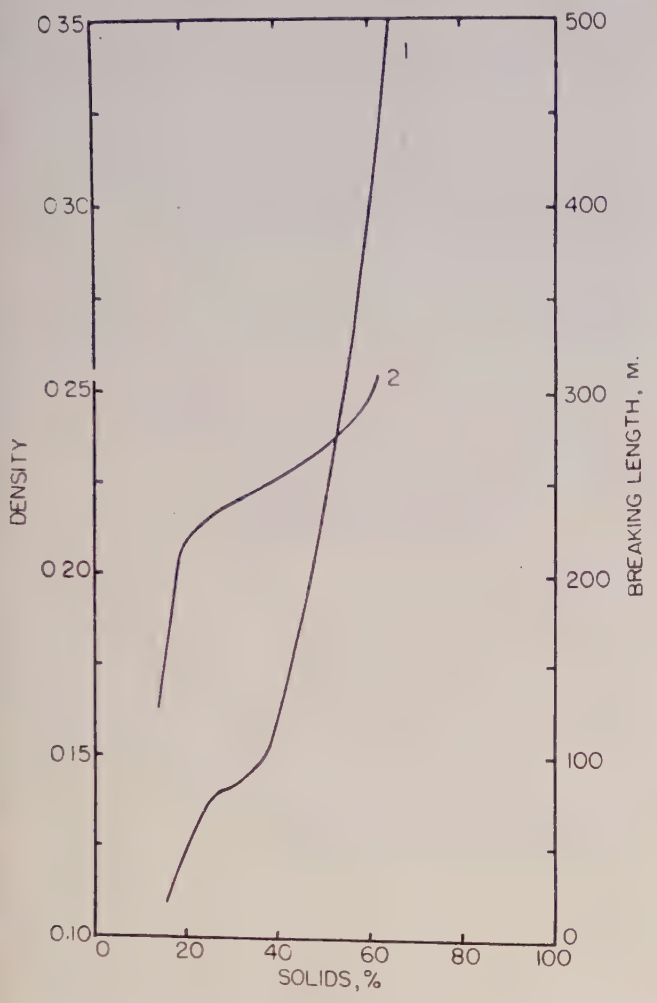

Fig. 22a

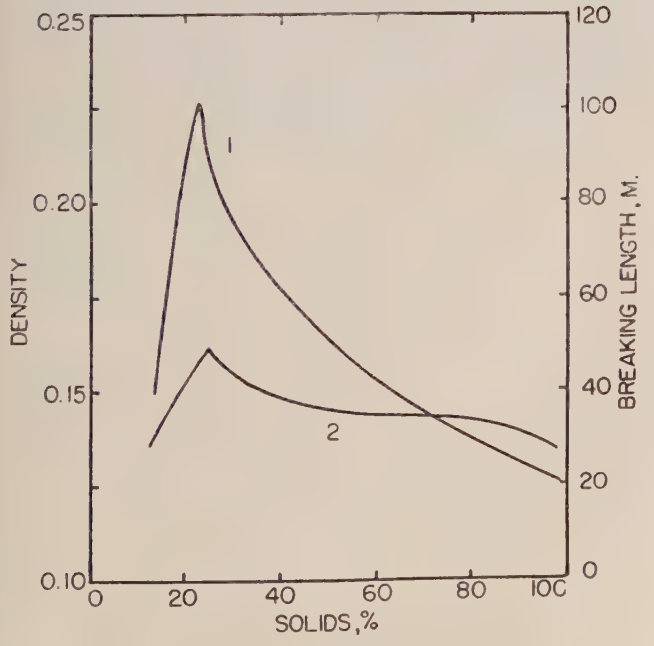

Fig. 22b

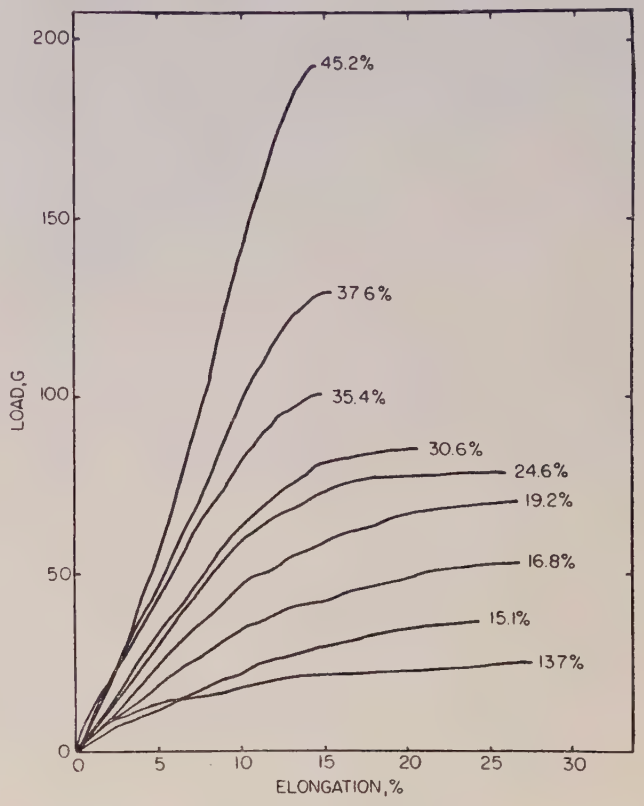

Fig. 22c

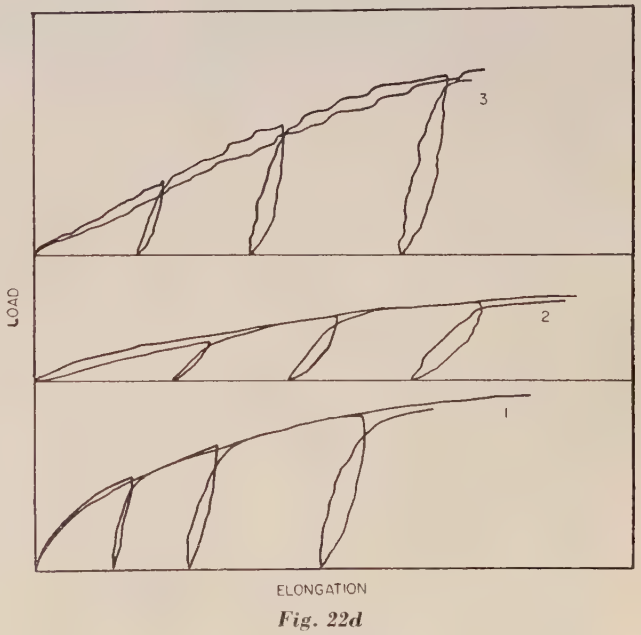

Fig. 22d

(a) Strength and density of spruce sulfite wet web as function of consistency. (b) Strength and density of glass fiber wet web as function of consistency. (c) Load-elongation relationship for spruce sulfite wet webs. (d) Load-elongation relationship for spruce sulfite, glass and groundwood wet webs with and without recycling *Gallay (50)*.

sion at several points through the press and drier sections. Many workers have studied breaking stress and strain which is the significant property practically. They have found for example a very rapid increase of strength as the solids content of the mat is increased, as the percentage of long chemical pulp is increased, and a loss of strength as the surface tension of the water is decreased by soluble additives. The work of Gallay and Lyne (*50, 51*) has been noteworthy in this field. They worked with mats of sulfite spruce fibers at various degrees of beating and with glass fibers of different denier. Although they recorded the stress-strain curves during their experiments, they relied to a large extent on breaking length values for the development of their theories. Working with mats of constant weight they measured caliper as a guide to mat density (Fig. 22) illustrate typical results. The glass fiber mat shows an increase of strength with solids content up to maximum at about 25% then a decrease. Pulp showed an inflection at about 25% and then began to increase rapidly once again.

Gallay suggests that the glass exhibits a single strength development mechanism—going through a maximum at 25% and that the pulp exhibits two mechanisms—one, equivalent to that in glass, plus a second which is negligible at low solids and increases rapidly above 25% reaching a maximum in the dry paper.

We will return to a discussion of the strength curves in the next section. The stress-strain curves (Fig. 22 (c),(d)) exhibit several viscoelastic features. There is no, or very little, true elastic portion, yield occurring at very low stresses, and in addition permanent set, creep, and memory are all present.

The stress-strain behavior of an elastic body are usually described in terms of four moduli, Youngs (E), bulk (K), shear (G), and Poisson's ratio (σ). These four are interrelated for an isotropic material, thus

$$K = \frac{E}{3(1-2\sigma)} \qquad G = \frac{E}{2(1+\sigma)}.$$

Barkas' analysis of the elastic constants of a web was in terms of those of a single fiber. The web is not as systematically arranged as he assumed—but is rather a loosely interlocked structure. Compression of the web therefore will not produce uniform compressive stresses on all the individual fibers, but rather flexing, localized compression, tensions, etc. in a complex manner. Thus, a distinction exists between fiber and web elastic constants.

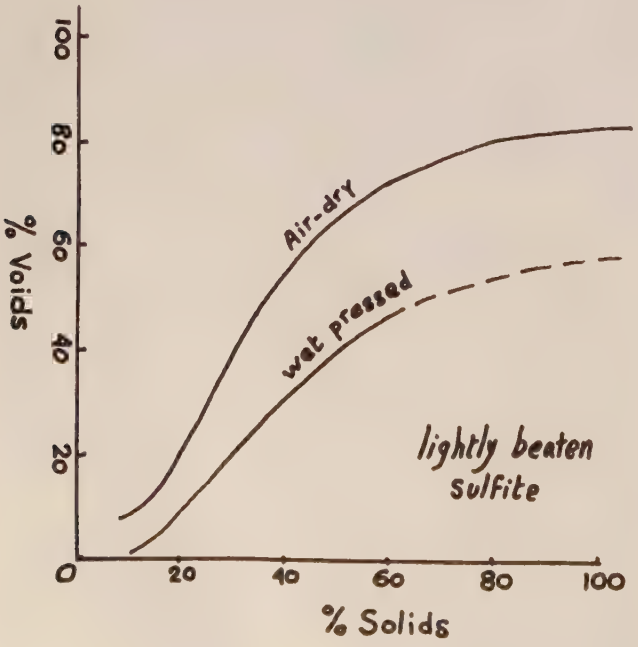

Fig. 23. Void space as a function of consistency (50)

Further work is required to clarify the interrelation of the "elastic constants" in the case of viscoelastic materials. At least three of them (E, K, and G) will be time dependent.

Neglecting the time dependent components of the moduli, I have found that the assumption that the bulk modulus is proportional to the applied pressure is sufficient to explain much of the reported work, and this proposition has several interesting consequences. Firstly it predicts Campbell's relationship—and supplies a physical significance to the two, otherwise arbitrary, constants m and n.

$$n = \frac{1}{k}.$$

where k is given by $K = kp$.

$$m = \frac{c_0}{(p_0)^n}$$

where

c_0 = the sedimentation consistency of the pulp
p_0 = the compacting pressure in sedimentation—due to the fibers, net weight in suspension.

Secondly, it predicts that $G' \alpha\ p$ and hence $c = m'G'^n$ and by using Kurath's data we have

$K = 3.12\ p$ dynes/sq. cm.
$G' = 53.7\ p$ dynes/sq. cm.
$\sigma = -0.778$
$E = 23.8\ p$ dynes/cm. and
$c = 0.002\ E^{0.32}$

This bulk modulus is of the same order as those reported by Barkas above. This derived relationship of Young's modulus and consistency is in good agreement with Gallay's data in Fig. 22 (c), up to 20% solids, beyond which the actual modulus is less than predicted due to the introduction of air into the web.

Another interesting observation is the approximate numerical agreement of c_0 with the critical consistency in shear flow. It would seem therefore that even in the absence of shear the fiber has a volume associated with it, larger than its own and which is related to the volume per fiber enclosed in a randomly laid down mat, under no external compacting force. A rather unexpected corollary is that at consistencies greater than about 0.2%, the fibers in a well dispersed pulp slurry form a loosely bonded network which is under compressive strain.

Extending these concepts by the introduction of a time dependent element in k, leads to a viscoelastic model, and provides a means for explaining such relationships as creep, complex shear modulus, etc. Recognizing the ability of suspensions to form networks at concentrations as low as 0.002 it is probable that some of the anomalous behavior of other non-Newtonian liquids can be explained in terms of network structures analogous to those observed in pulp suspensions. The shear dependence of viscosity determinations for pigment slurries, and polymer solutions may also yield to analysis by a network concept.

THE DRYING PHASE

Two aspects of the drying phase are of scientific interest, namely the mechanism of water removal and the development of the strength and of other physical properties of the paper.

The paper web is a three-phase system throughout drying. This fact is emphasized in Fig. 23 (from Gallay (*50*)). In the wet sheet the void space is made up of the larger capillary spaces. As drying proceeds the smaller capillaries are vacated. The rate of increase of void space is partially offset by the shrinkage of the web.

Various forms of drying are used in the paper industry. Air drying is still used for handmade papers and some coated grades. Drier cylinders contacting the two sides of the sheet alternately is the most common method. With lightweight papers a cotton felt is commonly used to hold the sheet against the driers. One sided drying on a single large diameter drier, a Yankee drier, is used on some grades and is used together with one or more high pressure rolls to get high heat transfer rates. Radiant heating and resistive heating are

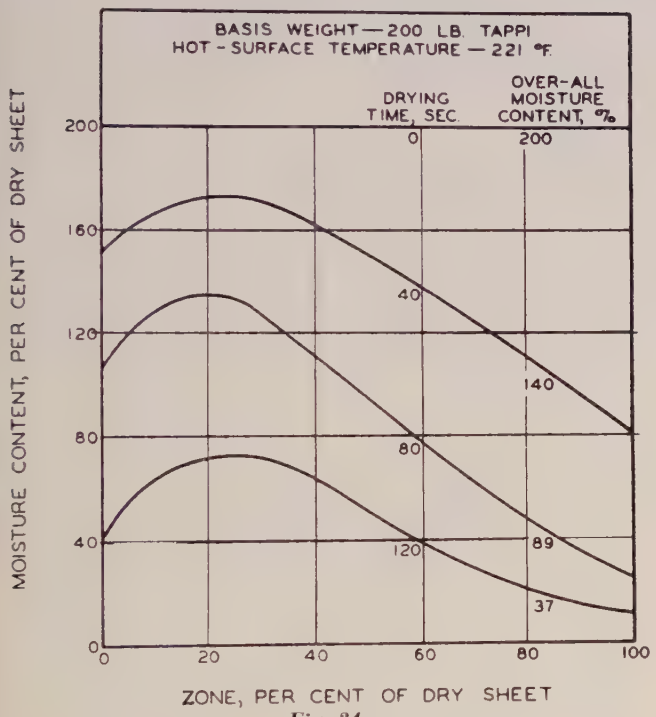

Fig. 24a

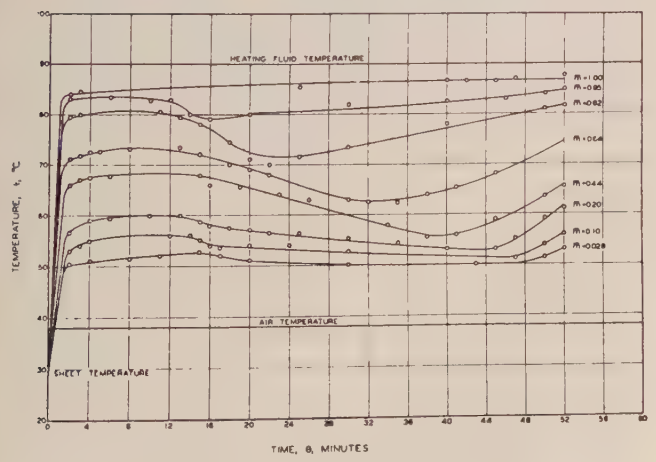

Fig. 24b

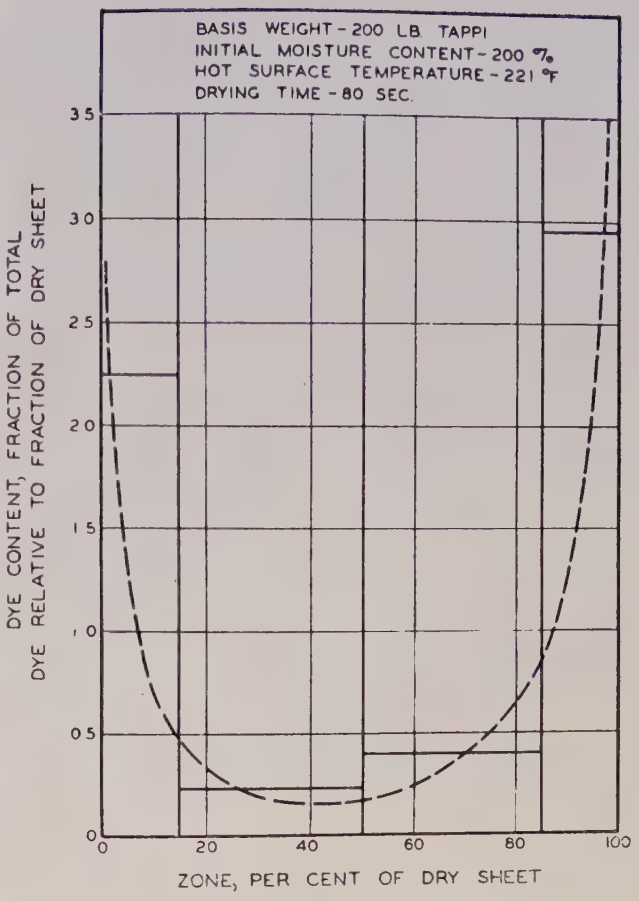
BASIS WEIGHT - 200 LB. TAPPI
INITIAL MOISTURE CONTENT - 200 %
HOT SURFACE TEMPERATURE - 221 °F
DRYING TIME - 80 SEC.
DYE CONTENT, FRACTION OF TOTAL
DYE RELATIVE TO FRACTION OF DRY SHEET
ZONE, PER CENT OF DRY SHEET

Fig. 24c

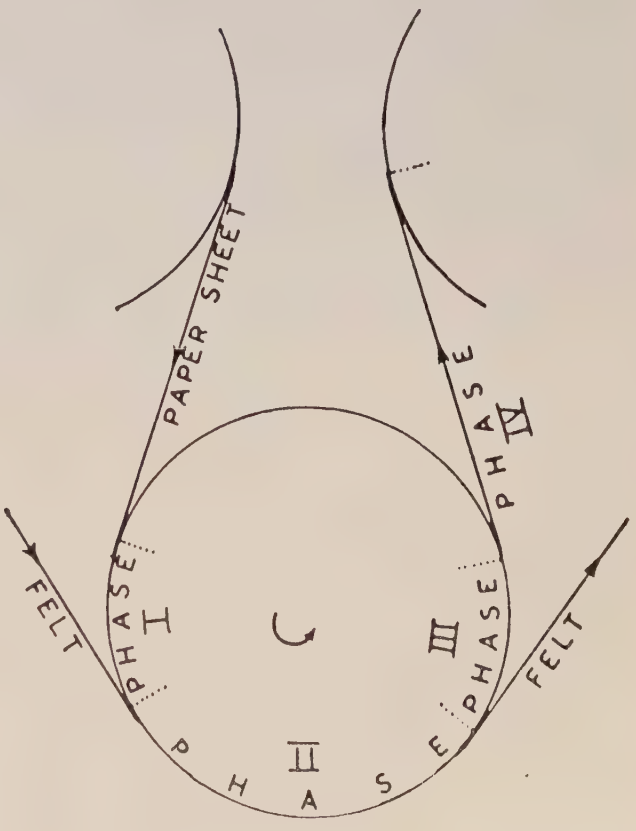

Fig. 24d

(a) Moisture profiles during hot surface drying (*53*). (b) Temperature profiles during hot surface drying (*54*). (c) Dye concentration profiles during hot surface drying (*53*). (d) The four phases of multicylinder drying (*58*).

occasionally used for supplementary heating. A recent development is the combination of hot surface heating on one side of the sheet with direct impingement of very high velocity hot air or superheated steam on the other. This method also produces high rates of heat transfer.

An early study of the hot surface drying of paper was that of McCready (*52*) who worked with a laminated pulp pad to follow the moisture and temperature profiles during the drying. He identified a constant drying rate period followed by one of falling rate which he considered was controlled by diffusion. No clear mechanism of diffusion was postulated in the early work although capillary diffusion was suggested as a possible mechanism. The equations used were those of diffusion, not of permeation, however.

A detailed study of the mechanism of hot surface drying has been carried out by Dreshfield and Han (*53*) and by Han and Ulmanen (*54*). They used laminated sheets with beta ray absorption to follow moisture profiles and a soluble dye technique to determine the course of water migration. Their data provides a comprehensive theory of the drying mechanisms involved in hot surface drying. Figure 24 (a),(b),(c) show typical profiles for moisture, temperature, and dye concentration as drying proceeds. Heat is supplied from the hot surface establishing a temperature gradient across the sheet. Evaporation occurs at the air surface, the moisture from the surface being replaced by the action of capillary suction forces. Evaporation also occurs at the hot surface and is likewise replaced. Vapor permeates from the hot toward the air surface under both an actual and a partial pressure gradient. At first much of this vapor condenses in the body of the sheet, enhancing the thermal conductivity. This moisture movement creates a humped distribution and the concentration of dye at the two evaporation sites. The relative dye concentration in the center begins to fall as a result of the condensation cycle.

Since Dreshfield's work another mechanism of moisture flow has been recognized which complements moisture flow by capillary action. This is surface flow within the adsorbed water layers on the fibers. From about 20 to 30% moisture (based on dry weight) can exist in the adsorbed phase and, with the exception of the molecules in the first tightly bound layer, rapid movement is possible to depleted sites. Surface flow becomes increasingly important at the end of the constant rate and at the start of the falling rate periods in webs of low permeability and where low partial pressure gradients exist.

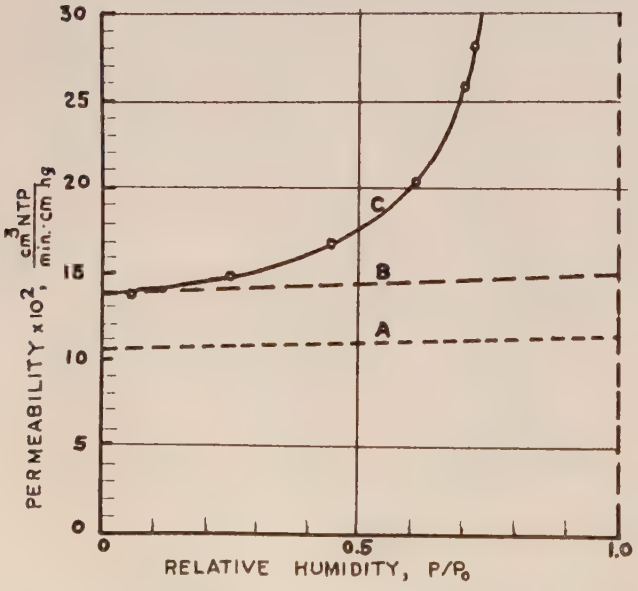

Fig. 25. Permeability of paper as a function of RH

Curve A for inert gas. Curve B calculated for water vapor from *A*. Curve C observed for water vapor.

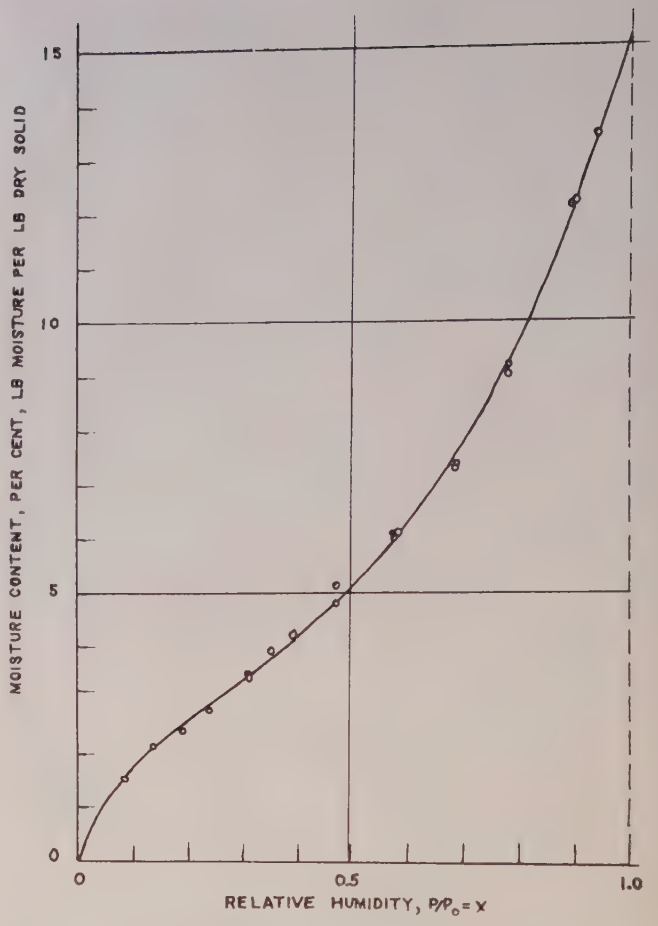

Fig. 26. Sorption isotherm for cellulose with Rounsley's theoretical curve fitted

Eventually the rate of movement to the evaporation sites is too slow and the drying rate begins to fall, the sites of evaporation moving into the sheet. Thermal conductivity, vapor permeability, and surface flow now become rate controlling factors.

The correlation of vapor permeability and relative partial pressure has been studied by Vollmer (*55*). Figure 25 shows a typical relationship. Curve A represents the permeability measured with an inert gas. Curve B is the calculated curve for water vapor correcting for its different molecular weight. Curve C is the observed relationship. The difference between the two is the measure of moisture movement in the adsorbed layers. This difference varies with flow rate, it increases initially with flow rate but eventually reaches a constant value. Rounsley (*56*) has derived an equation for multimolecular adsorption which may be used to correlate the amount of water in the adsorbed layer with the relative humidity. He assumed the first molecular layer is tightly bonded, with an energy of adsorption greater than that for the subsequent molecular layers

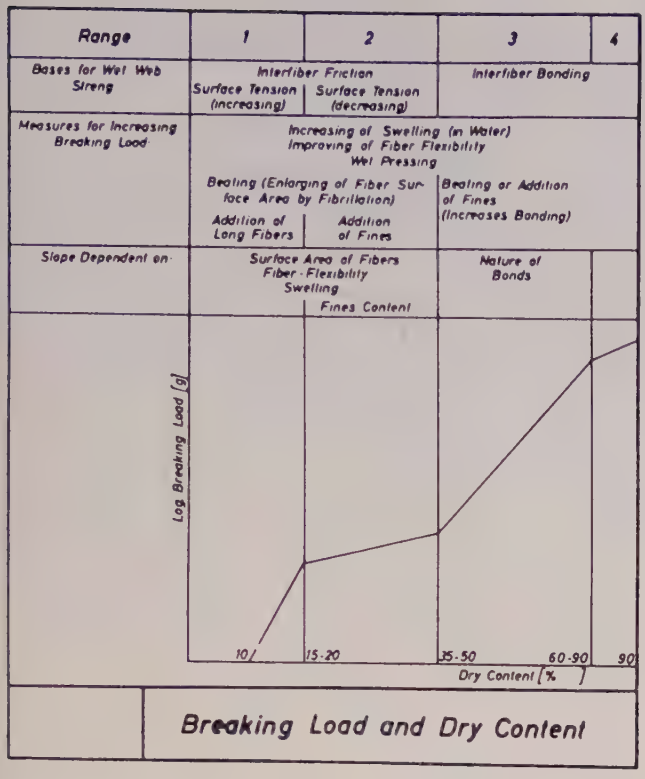

Fig. 27. Effect of various factors on breaking load vs. dry content curve (60)

which he assumed approximates the energy of condensation. The molecules in the outer layers are free to move over the surface. The number of molecular layers is assumed limited and in the range four to six and condensation into a given layer is governed by statistical thermodynamic considerations. Figure 26 shows the fit of Rounsley's equation to a typical sorption isotherm for cellulose.

$$A = \frac{B.C.x}{1 + (C-1)x} \cdot \left[\frac{1 - x^n}{1 - x}\right]$$

Unlike the B.E.T. isotherm (*57*) equation to which Rounsley's degenerates at low R.H.'s, this equation holds over the entire humidity range.

Down to about 7% (the amount of moisture associated with the bound layer), surface flow provides a mechanism of rapid moisture flow.

How far are these concepts applicable to actual operation? Han (*53*) suggests they may be used directly for Yankee drying if allowance is made for the very high porosity of sheets commonly made on these driers. On multicylinder driers the sheet only spends a very short period on each drier, and the temperature profile may not have time to reach equilibrium. This process is concerned then with transient conditions. In addition both sides of the sheet are repeatedly exposed to the air so that vapor diffusion through the sheet from the hot surface is not the only possible means of drying from this side. Evaporation from the hot side in the succeeding draw is an additional mechanism available in multidrier systems. Nissan (*58*) has also indicated another, which occurs primarily on the early driers. Up to 40% additional drying may result on these early driers from the evaporation of the water film left behind on the drier surface when the sheet leaves it. The presence of a felt over the sheet for part of the cycle is a further complication. The felt prevents direct evaporation to the air and, depending on its own moisture and temperature condition, may remove water by capillary action, by absorption of vapor with or without condensation or it may even transfer water back to the sheet. In all, four distinct phases of drying occur for each cylinder. These are shown in Fig. 24d.

Nissan (*58*) has shown that accurate predictions of the constant drying rate can be made by assuming the sheet behaves on the cylinder as a solid with respect to heat transfer, that its conductivity is a function of moisture content, and that evaporation from the air surface follows regular free surface evaporation equations. In another paper (*59*) an approach to the falling rate period has been suggested using the concept of a pseudo-wet bulb condition at the retreating plane of evaporation. So far this technique has been restricted to coarse porous sheets in which surface flow effects would be small.

The rapid development of strength properties during the drying process is a striking feature of the drying phase. Sheet shrinkage, particularly in thickness, is another.

In the section on wet web rheology I referred to Gallay's studies of the tensile strengths of glass and of cellulose fiber webs. In the former case the strength rose as the web was dried until it reached a maximum value at about 25% solids after which it decreased almost to zero. Cellulose on the other hand showed an inflection at about 25% but then continued to increase rapidly until the end of drying. Figure 27 summarizes a study by Brecht (*60*) of the way different variables affect this strength development. Gallay pointed out that an adhesive added to the glass-water system produced similar results as did water alone in the cellulose case. Broughton (*61*) studying the strength development of cellulose fibers in butyl alcohol, toluene and water, found that the strength development from the nonpolar liquid systems was at a much lower rate than for water but of a similar general shape. A very interesting further observation was the fact that the butyl alcohol sheets, if subsequently exposed to a relative humidity of 85% and then redried, attained the full strength potential of the water dried sheets. A partial explanation of these effects is possible. Gallay identified surface tension as the controlling factor, in all phases, but his explanation of the mechanisms involved has received some criticism (*62*). In the very wet web the liquid forms a continuous phase, enveloping the fiber mat. The action of the surface forces is to apply a compressive strain to the entire mat. This in turn increases fiber-fiber frictional forces and so mat strength. As 25% solids is approached the resistance of the mat to further compression is such that with further removal of water the surface of the liquid begins to recede into the mat, leaving some fibers exposed. These fibers no longer experience the same compressive forces and the mat begins to expand again, with a loss of overall strength in the case of the glass. To explain the continued strength development in the case of cellulose Gallay recalled the work of Campbell (*39*) who had shown that the water in the mat collects at points of fiber intersection and because of the concave meniscus formed is capable of pulling the fibers together with enormous forces, so that the fibers approach close enough for chemical bonds to form. The existence of these forces is not disputed by anyone, particularly dur-

ing the latter part of the drying phase. Hunger (*63*) in particular has studied the effect of these forces on the fibrillar structure of the fiber itself. The difficulty in accepting the hypothesis of bond formation as the sole mechanism from about 25% solids up is the fact that in order for chemical bonds to form the surfaces must be brought within about 1 A distance from one another. In the wet state, fibers are covered with adsorbed water layers and the potential bonding sites are already satisfied with water molecules. Only when the solids content begins to rise above about 65% is it probable for a few free bonding sites to exist and for the surface tension to cause contact on an atomic scale to any great extent. What then is the reason that cellulose continues to develop strength between the end of the continuous liquid phase and the onset of chemical bonding while glass does not? A possible explanation in the case of cellulose is the continued growth of fiber-fiber frictional forces as the fibers are drawn together by surface tension forces. This idea is supported by Broughton's work with the nonpolar liquids, which possess surface tension but which do not have the bond forming ability of water. The ability of a humid atmosphere to develop the full strength at a later time confirms that the nonpolar liquids had brought the surfaces into close atomic proximity in the same way as water. The lower strength in the early stages may be explained by the lower surface tensions of butyl alcohol and toluene and in the latter stages by the small number of available bonding sites on unswollen fibers. Unfortunately this plausible line of argument could only explain the lack of strength development in glass webs between 25 and 65% solids if we assumed water and glass have a negative angle of contact and water could not draw glass fibers together or else that the coefficient of friction for glass-glass contact is zero. This is not so; why then the difference? Obvious differences between glass and cellulose fibers are the physical and chemical natures of their surfaces. Cellulose possesses fibrils, glass is microscopically smooth. Maybe it is not accidental that two of the "adhesives" Gallay found to develop strength with glass (*51*) are known to etch the surface of the glass. The two fibers also have very different rigidity moduli. A further difference is the very pronounced twisting which a cellulose fiber experiences as it dries. The effect of these torsional strains is to assist the compressive forces due to surface tension in promoting frictional forces. Glass has no such property. We could say the glass has a very low coefficient of friction compared to cellulose fibers, but such a statement would contribute little to our understanding unless we could then explain the reason for this difference in terms of the current theories of friction between solids.

In conclusion, the mechanisms proposed are only partially acceptable. Until such time as we are able to explain the anomalous behavior of the glass webs, the explanations proposed for strength development in cellulose webs are in need of refinement. Additional research in this field is indicated.

ROLLS AND BOWLS

Rolls, singly, in pairs, and in stacks are used at every stage of the papermaking process. In a number of cases, pairs of rolls are used together under pressure to form a metering nip. In the press section they meter a viscoelastic wet web and felt and in doing so extract water. In the size press and the coating press they meter non-Newtonian liquids. At the various calender stacks they meter a dry web and by plastic flow obtain improved surface smoothness. Some of the rolls are of stone or metal and may be considered incompressible. Others have softer surfaces of rubber, paper, or cloth. In a wet press one roll usually has a drilled surface, which in combination with a woollen felt acts as a permeable surface. While a start has been made to study these numerous problems (*64–70*) much remains to be done. Unfortunately lack of time prevents their discussion in this paper and the interested reader is referred to the literature cited above. The particular problems involved are very common throughout a wide

Nomenclature

Q	= flow rate through filter mats [vol./time]
A	= area of filter mat
ρ	= density of liquid filtrate
ν	= kinematic viscosity of filtrate
L	= thickness of filter mat.
Δp	= pressure drop across the filter mat
c	= consistency of the fibers in mat, g./g.
c_s	= consistency of the fibers in slurry
v	= hydrodynamic specific volume of pulp vol./unit wt.
S_w	= specific surface of pulp on a unit wt. basis
S_v	= specific surface of pulp on a unit volume basis
k	= Kozeny "constant"
p	= pressure applied to mat at a given point
m,n	= compressibility constants in Campbell equation
C_0,m_0	= compressibility constants in Wilder equation
a,b	= constants of Kozeny "constant" equation
γ	= dimensionless consistency at a point in the mat = $\frac{\text{effective consistency}}{\text{slurry consistency}} = \frac{c}{c_s}$
$\delta(t)$	= mat thickness at time t in Meyer equation
η	= dimensionless coordinate of a point in the mat = $\frac{\text{distance from wire}}{\delta(t)}$
t	= time
s, or $s(t)$	= volume fraction occupied by effective (retained) fibers in the mat $s = cv$
s'	= time derivative of s
N	= $\frac{1}{n}\left(\frac{1}{vm}\right)^{1/n}$
D	= $\frac{1}{aS_v}$
K	= $\frac{1 - 5/2n}{n}$
r	= $\frac{1 - n}{n}$
C^*	= $\frac{1}{\gamma_{3/2}\,[1 + b(s\gamma)^3]}$
I_0	= $\left[C^*(\gamma - 1)^r \frac{\partial \gamma}{\partial \eta}\right]_{(\eta = 0)}$
s_{wo}	= volume fraction of fibers in filtrate at $t = 0$
s_s	= volume fraction of fibers in slurry
β	= constant
$B(t)$	= basis weight of mat formed up to time t
e	= exponential function
m^*	= complex constant with components m' and m'', in shear modulus equation
G^*	= shear modulus with real and imaginary components G' and G''
$Q(f,g)$	= Kurath's function
f	= number of fiber-fiber contacts in mat
g	= average normal force at each contact
K	= bulk modulus
E	= Young's modulus
σ	= Poison's ratio
A	= amount of water absorbed/unit mass of cellulose
B	= amount of water absorbed/unit mass of cellulose per monolayer
C	= ratio of the total partition function for the first layer and of the succeding layers
x	= relative partial pressure
$\bar{n}$	= average number of molecular layers possible

sector of industry, for example, steel rolling, plastic and metal foil production, textiles and printing to name a few.

CONCLUSION

The science of papermaking is, to a very great degree, a study of multiphase systems. Initially we are dealing with a two-phase, liquid and fibrous solid system. At a relatively early stage the entry of air into the system changes it to three phase. The fibrous nature of the solid phase has the remarkable effect of creating solidlike behavior in a system which consists of as high as 99.8% liquid, and this feature dominates most of the process. The effects of surface tension are manifest in a variety of ways throughout the entire process ranging from macroscopic effects at the beginning to microscopic ones at the end. The exceptional relationships between cellulose and water with respect to swelling and to hydrogen bonding present complex but interesting problems at all stages. Finally, the variability and complexity of structure associated with raw materials which are of natural origin is sometimes frustrating but at all times intriguing.

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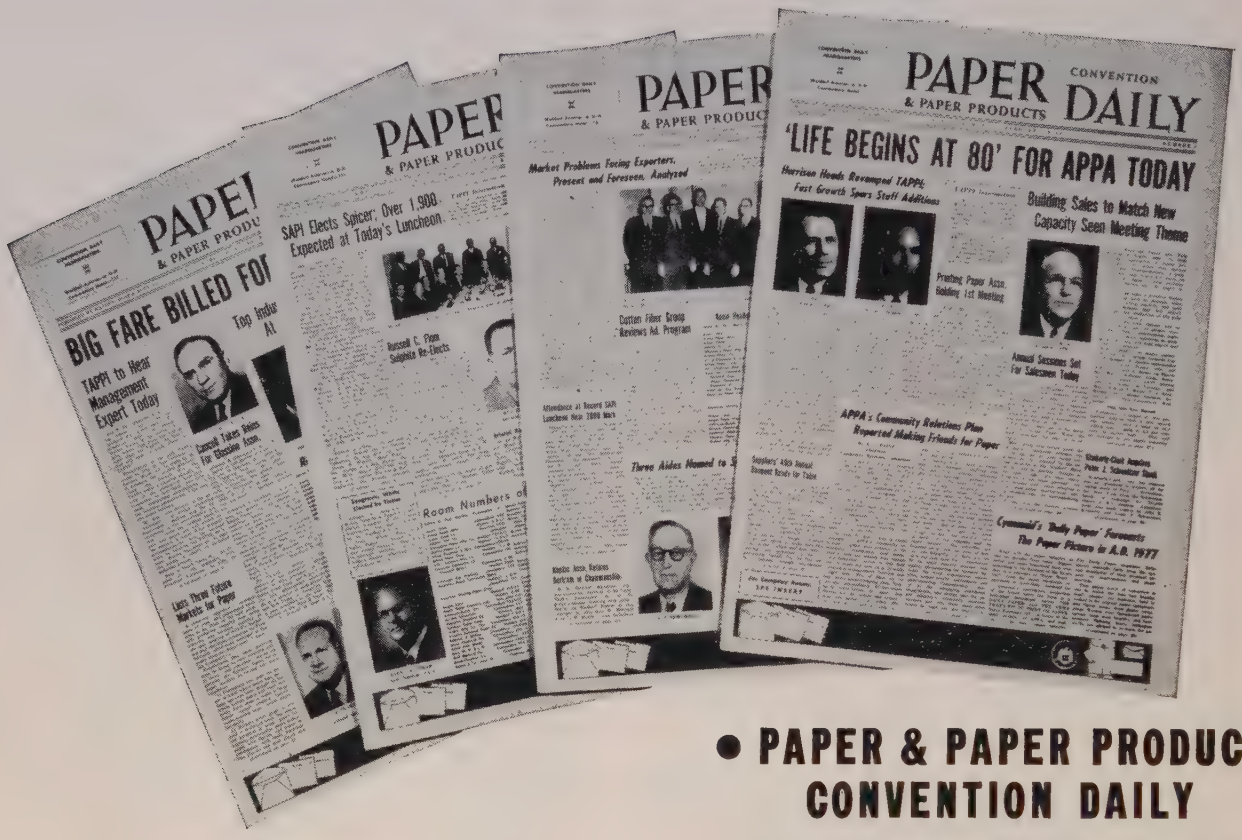
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